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Entrance Head and Discharge Head in Pipes

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ENTRANCE HEAD AND DISCHARGE HEAD IN PIPES

BY

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This is to certify that the following thesis prepared under the direction of Professor A. N. Talbot, Head of the Department of Theoretical and Applied Mechanics, by

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entitled ENTRANCE HEAD AND DISCHARGE HEAD IN PIPES

is hereby approved by me as fulfilling this part of the requirements for the Degree of Bachelor of Science in Civil Engineering.

Ira O. Baker.

Head of Department of Civil Engineering

ENTRANCE HEAD AND DISCHARGE HEAD IN PIPES.

It has long been known that the shape of both inlet and discharge ends of a pipe greatly affects its discharging capacity for a given head. A converging inlet is known to cause a decrease in the loss in head due to entrance, and a diverging outlet, when flowing full, has been proven to be of aid in raising the coefficient of discharge. Venturi, in 1791, decided that a maximum value of c of 1.46 would be obtained when the length of the diverging outlet was nine times its least diameter, the angle at the vertex of the cone being 5°-$06'$. In 1854, Francis obtained a coefficient of discharge of 2.43 with a pipe slightly over one inch in diameter and a mouthpiece three feet long, or thirty-six times the least diameter. (See Merriman's Hydraulics, p. 187, '04 Edition.)

All the experiments referred to above were made with small pipe, not over two inches in diameter. In 1903 Mr. W. P. Ireland experimented at the University of Illinois with conical inlets on 6-inch and 12-inch pipes, and showed that the laws regarding flow in the small pipes applied equally well to larger ones. In order to obtain low heads, he submerged the pipe, and found that for low velocities the rate of discharge was greatly increased, while for high velocities the gain was not so noticeable. (See Thesis "1903 Ir. 2", U. of I. Library.)

As little was known of the coefficients for the mouthpieces on the discharge end, Mr. C. C. Wiley conducted a series of experiments in 1904, at the University of Illinois, which further established the value of mouthpieces on both inlet and discharge ends. His experiments, which were quite thorough, were made with mouthpieces of various angles and of such lengths that the area of the outer end was twice the area of the pipe. Mr. Wiley's results are summed up in Tables 5&6.

Since, theoretically, the longer the diverging mouthpiece on the discharge end, the better will be the results, it was thought that experiments would be of value which dealt with mouthpieces of such length that their area at the outer end would be three times, or even four times, the area of the pipe.

In this thesis the effect of this extension of the mouthpiece is given and additional data on the coefficients of entrance head and discharge head are recorded. The order of presentation will be as follows:

I. Theory of flow of water through pipes.

II. Methods used in the experimental work, and discussion of the sources of error.

III. Explanation of tables and plates.

IV. Discussion of the results and conclusions.

I.

FLOW THROUGH PIPES.

The head which causes flow through a pipe is taken up in three ways, (1) by entrance head, which includes the loss from contraction and expansion of the stream, (2) by friction with the sides of the pipe, and (3) by giving velocity to the stream. The expression which shows the above conditions is, $h = m\frac{v^2}{2g} + f\left(\frac{l}{d}\right)\frac{v^2}{2g} + \frac{v^2}{2g}$, where h is the total head causing the flow, $m\frac{v^2}{2g}$ represents the entrance head, $f\left(\frac{l}{d}\right)\frac{v^2}{2g}$ is the loss due to friction, and $\frac{v^2}{2g}$ is the head causing velocity. v is the average velocity in the pipe in feet per second, g is the acceleration of gravity, l is the length of the pipe in feet, d is its diameter in feet, f is the coefficient of friction, and m is the coefficient of loss due to entrance. The term $\frac{v^2}{2g}$ is what is commonly termed "velocity head".

In a short pipe, the diameter is large as compared with the length, hence the friction loss is quite small. An experiment made on a 6-inch pipe 22 1/2 inches long, with a head of .75 ft. showed a velocity of 5.48 ft. per second. The velocity head corresponding to this is 0.47 ft.. Remembering that there is a contraction of section at the entrance end, it is probable that the water fills the pipe at about two diameters from the end, say 10 1/2 inches. The friction factor for this case is 0.022. (See Merriman's Hydraulics, p 559, '04 Edition.) Substi-

tuting these values, we have $f\left(\frac{l}{d}\right)\frac{v^2}{2g} = .022\left(\frac{1.0}{0.5}\right)(0.47) =$ $.0206$ ft . The loss due to friction in this case is then 2.75% of the total head. As this is small, even when the velocity is much larger than any used in the experiments the term $f\left(\frac{l}{d}\right)\frac{v^2}{2g}$ will be dropped from the expressions used in this thesis.

The expression to be used, then, reduces to $h = m\left(\frac{v^2}{2g}\right) + \frac{v^2}{2g}$ or $h = (1+m)\frac{v^2}{2g}$. The value for m is obtained from the expression $m = \frac{1}{c_1^2} - 1$, (See Merriman's Hydraulics, Art. 85, '04 Edition.), where c_1 is the coefficient of ~~discharge~~ velocity obtained by dividing the actual discharge by the theoretical discharge, which is $a\sqrt{2gh}$, where a is the cross-section of the pipe in square feet.

The term m applies only to entrance, consequently in the above expression there is nothing to show the effect on the discharge of the condition of the discharge end of the pipe. It is evident that a diverging outlet regains some of the velocity head, so if this regained head is called $n\frac{v^2}{2g}$, the complete equation would be $h = (1+m-n)\frac{v^2}{2g}$ or $h = (1+m')\frac{v^2}{2g}$, where $m' = m-n$ = combined effect of the entrance and discharge ends. Then,

$$m' = m-n = \frac{1}{c_1^2} - 1 \quad .$$

In order to find the effect of the entrance and discharge ends separately, it is necessary to find the values of m and n. The value of c for each experiment was determined by dividing the actual by the theoretical discharge. Knowing c, we can obtain (m-n), because m-n $= \frac{1}{c_1^2} - 1$.

If there is no mouthpiece on the discharge end, n does not enter the equation, and m may be determined. When a mouthpiece is on the discharge end, (m - n) may be determined by finding c. Then, if there is no inlet mouthpiece, the value of m for the plain pipe being known, the value of n may be easily computed. If one mouthpiece be put on the inlet end and another on the discharge end, the value of m - n obtained by experiment ought to be near the difference of the values of m and n obtained separately. Experiments bear out this statement.

The amount of velocity head which may theoretically be regained is determined as follows;- if the outer end of a diverging outlet is, say, twice the area of the pipe, the velocity at the end is half that in the pipe, and the velocity head is one-fourth as great. So the maximum theoretical n for this condition would be .75. Likewise the maximum is .88 where the ratio of areas is one to three, and for one to four mouthpieces, .94 is the maximum.

II.

METHODS USED IN THE EXPERIMENTAL WORK AND A DISCUSSION OF THE SOURCES OF ERROR.

In the experiments herein described a cylindrical cast-iron discharge pipe, 6-inches in internal diameter and 22 1/2 inches long, was used to connect the two compartments of the box through which the water flowed. It was threaded at each end and near the middle was flanged to permit of being attached to the box. (See Plate 1)

In these experiments, seven diverging mouthpieces and one ring, threaded to fit the discharge pipe, were used. For their dimensions, see Plates 2 and 3. Each mouthpiece diverged at a known angle from the axis of the discharge pipe. One (5°) was of such length that the area at the outer end was twice that of the discharge pipe. Five were made (10°, 15°, 20°, 30°, and 45°) so that the ratio of areas was one to three, and one (20°) was made so that the ratio was one to four. The outside diameter of the ring was the same as that of the outer end of the 1 to 3 mouthpieces.

The discharge pipe was placed horizontally through a water-tight partition which divided a water-tight box into two parts. Water was admitted into one compartment, flowed through the discharge pipe into the second part and out through two vertical rectangular openings to the pipe which led to the measuring pit. The vertical openings

were covered by baffle-boards which kept the water at any desired height. The difference in level in the two compartments, which was the head causing the flow, was measured by means of two vertical glass tubes, one from each compartment, which were placed one on each side of a scale reading to millimeters.

The water, discharged, was measured in a circular pit, the mean diameter of which was 7.995 feet. A float and level rod, graduated to hundredths of feet, were used in measuring the rise in the pit.

All of the mouthpieces were tested on the discharge end and the 20° (1 - 3) was tested on the inlet end. One combination was tried, 20° (1 - 3) on the inlet end and 5°(1 - 2) on the discharge end, as it was in those positions that the above mouthpieces gave the best results.

A set of experiments consisted of readings taken with the pipe under from six to eight different heads, each experiment being repeated as a check.

In making these experiments, the water was wasted until running at a steady head, then was measured for a convenient length of time, and wasted again.

The diameter assumed for the pit is that used by Mr. C. C. Wiley in his experiments. It was the mean of thirty readings carefully taken. The largest variation from the mean of these measurements was .008 feet. Hence, the maximum error will not be over 0.10%.

In measuring with the float and level-rod, the

greatest variation in reading would not be over .005 ft. The maximum error would therefore occur when the smallest rise, 0.285 ft., was recorded. This case would give a maximum error of 1.75%. This was an exceptionally small rise and the possibility of error in the other experiments would be much less.

The water stood so still in the tubes for measuring the head that readings could easily be taken to 1/2 millimeter, or .0015 ft. The largest error would be when the smallest head, .008 ft., occurred. This would give a maximum error of 18.75%. Such a low head as this occurred only three times during the experiments, and the important results are not those deduced from experiments with low heads. The average head used would give a much smaller error from this cause. Thus, with a head of, say .250 ft., on the discharge pipe, the error would be 0.65%.

Time was taken with an ordinary watch, to the nearest second. The shifting of the waste pipe took only 1/2 second or less, consequently the maximum error would occur when the shortest time, 65 seconds, was used. This maximum error would be .77%.

Since all of these conditions for maximum error will not exist at the same time, and since it is the square root of <u>h</u>, and not <u>h</u> itself, which occurs in the results, it is possible that the greatest error in the final results, under low heads, is not over 6%. Probably as the heads become higher, there is no case where the error is over 1%.

III.

EXPLANATION OF TABLES AND PLATES.

The matter contained in the tables and plates will be arranged as follows,-

Table 1. General results of the experiments, giving the readings taken and the constants deduced.

Table 2. gives the values, for different velocities, of m - n, m, and n, for each mouthpiece.

Table 3 shows the mean values of m - n for a velocity of 0.7 ft. per second and for velocities greater than 3 ft. per second.

Table 4 gives the reduction in m' due to the use of mouthpieces as compared with a plain cylindrical pipe.

Table 5 gives values of m for each mouthpiece for different velocities.

Table 6 shows the values of n for each mouthpiece for different velocities. Included in Tables 5 and 6 are the results obtained by Mr. C. C. Wiley.

Plate 1 is a sketch of the discharge pipe used in the experiments.

Plates 2 and 3 show the dimensions of the mouthpieces used.

Plates 4 to 14, inclusive, show the relation of m - n to the velocity for each mouthpiece. The curves were plotted from the data used in Table 1.

Plates 15 to 24, inclusive, show the reduction in m', for the various velocities, due to the use of mouthpieces.

The data were taken from Table 4.

Plates 25 to 32, inclusive, show the relation of the velocity to $\underline{n}$ for each mouthpiece used on the discharge end.

Plate 33 shows the variation in $\underline{m}'$ for different mouthpieces. The reduction in $\underline{m}'$ as compared with the plain pipe is also shown.

Plate 34 shows the amount of velocity head utilized by the different mouthpieces, one curve being for the 1 to 2 set of mouthpieces, the other for the 1 to 3 set.

IV.

DISCUSSION OF THE RESULTS AND CONCLUSIONS.

From the data experimentally determined, the following conclusions may be drawn:-

(1) For velocities through the discharge pipe greater than 2.0 feet per second, the value of $\underline{m}$ and also of $m - n$ remains practically constant for any given condition of inlet and discharge ends.

(2) As the velocity decreases below 2.0 feet per second the value of $\underline{m}$, and also of $m - n$ increases. No explanation of this fact has been given as yet. If the pipe were not submerged at the outlet, the reason would be apparent. When the pipe is flowing full, however, it would seem that a low velocity would be conducive to better results than the high ones. Low velocities would seem to give the least tendency toward contraction of section in entering the pipe.

(3) Only one set of experiments was made with a mouthpiece on the inlet end. For this reason no very definite conclusion may be drawn as to the effect of lengthening the converging inlet. However, since a 20° (1 to 2) inlet mouthpiece gave an average value of $\underline{m} = 0.20$, and a 20° (1 to 3) inlet mouthpiece gave an average value of $\underline{m} = 0.14$, it seems that the longer the mouthpiece, the better will be the results. The limits within which this holds true can only be determined by further experiments.

(4) For velocities higher than 2.0 ft. per second, the value of n, for any one mouthpiece, remains practically constant. For velocities less than 2.0 ft. per second, it was found that values for n vary somewhat, but are almost the same as for the higher velocities. For different angles of mouthpieces, the values of n vary greatly, from .05, when the ring was used, to .66 for the 10°(1 to 3) mouthpiece, and .70 for the 5°(1 to 2) outlet, dropping then to 0.00 for the plain pipe.

The reason for the small value of n, when large angles are used, is that the broadening of the pipe is so sudden that the stream of water does not expand uniformly to fill it, and therefore, the velocity in the center is much higher than at the edge. With a long mouthpiece and small angle, the stream is given sufficient time to expand uniformly and a large value for n results.

From these results, it appears that the efficacy of the diverging outlet, for any given angle, is about constant for all velocities.

(5) Since both inlet and discharge mouthpieces are of benefit, a combination would produce still better results. The value of m - n for the combination is nearly the same as the difference of the values of m and n obtained for the mouthpieces separately. From the separate values obtained, it was evident that with the 5°(1 to 2) mouthpiece on the outlet end, and some inlet of less than 30°, the best results would be obtained. Experiments were made

with the 5°(1 to 2) mouthpiece on the outlet end and the 20°(1 to 3) mouthpiece on the inlet end. The results gave a coefficient of discharge of about 1.38, m - n being equal to -0.47.

(6) It is very evident from the above results that these experiments could be carried further with profit. These results show plainly that the smaller angles on the discharge end give the best results. The 5° mouthpiece is much better than the 10° one. Since Venturi's best result was obtained with an angle of $2^\circ - 33'$, and Francis' highest coefficient came from an angle of $2^\circ - 5'$, further experiments might be made to determine the angle which gives the best results.

The length of the discharge mouthpiece is also of importance. Theoretically, the longer the mouthpiece the better are the results which may be obtained. The longest mouthpiece used in the experiments had a length of nearly 2.4 times the least diameter. Referring again to previous experiments, it is seen that Venturi's best results came from a mouthpiece whose length was nine times the least diameter, and Francis used one thirty six times its least diameter. Future experiments should determine the ratio of length to least diameter which gives the best results.

A good application of the conditions stated in this thesis may be made in the construction of culverts where the water is likely to back up, as behind a railroad emmankment. Naturally, the water should be removed as soon

as possible, and a concrete culvert, built with a spread at the outlet corresponding to a mouthpiece, would assist materially in the speedy running off of the water. Also by this method, a smaller water-way may be used than is necessary with culverts of the ordinary type and consequently the cost of construction would be less.

Work of this kind is interesting and, as shown above, there remains much to be done in further investigation of the problems presented.

PLATE 1.

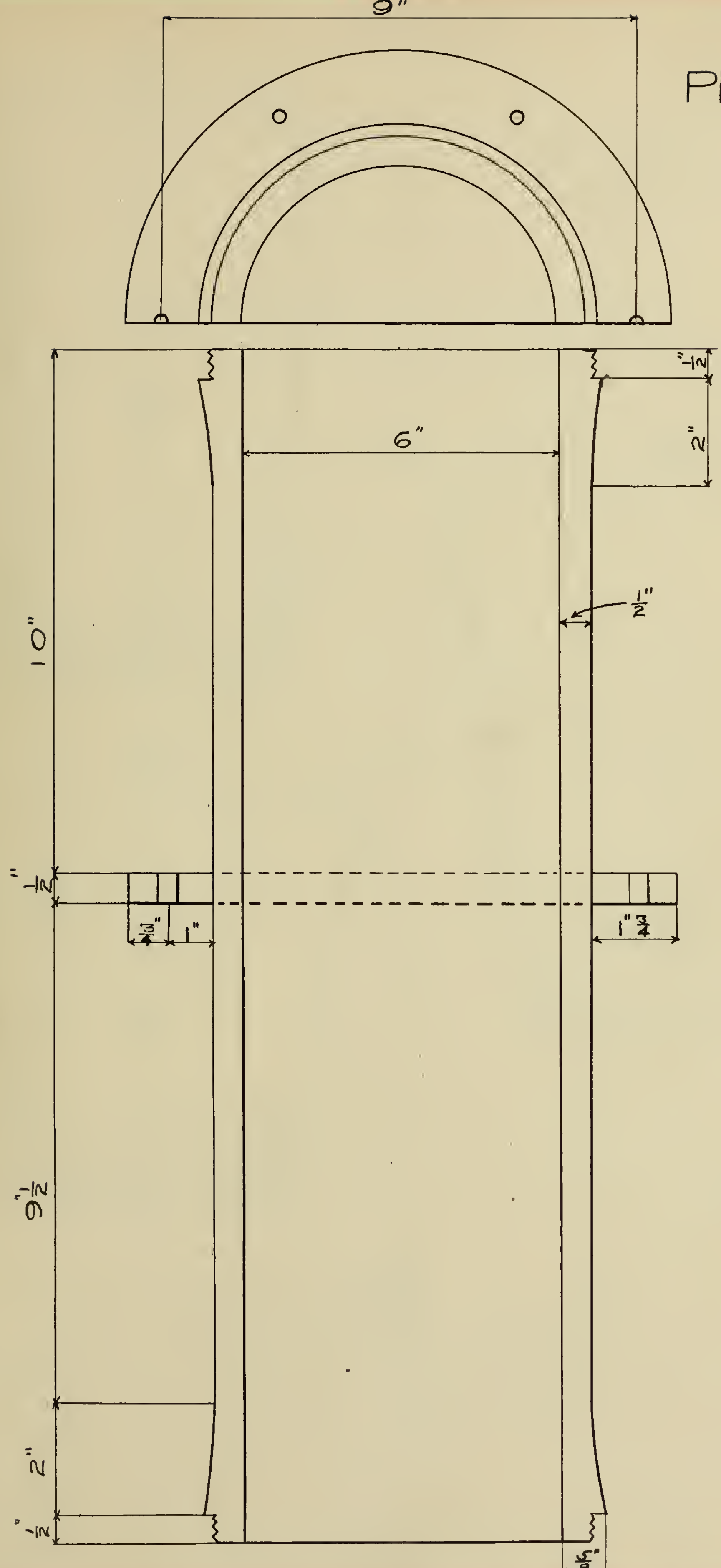

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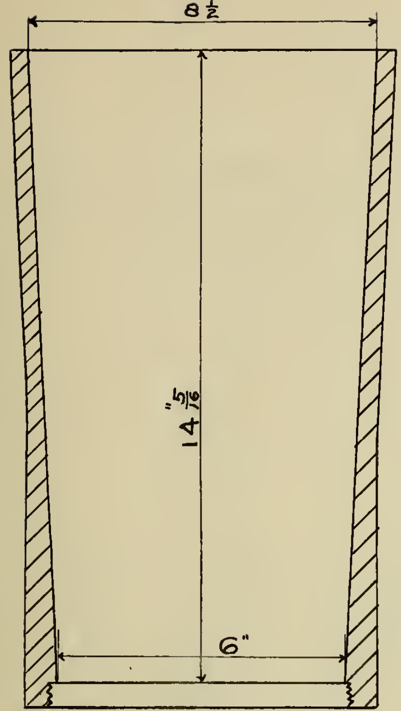
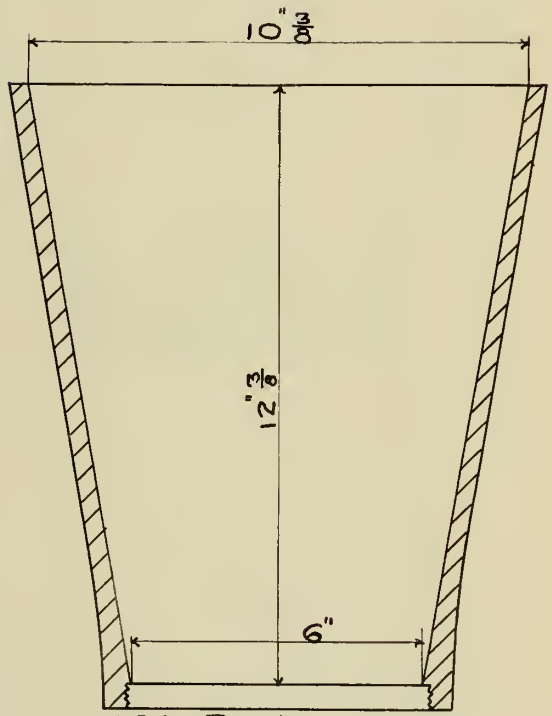
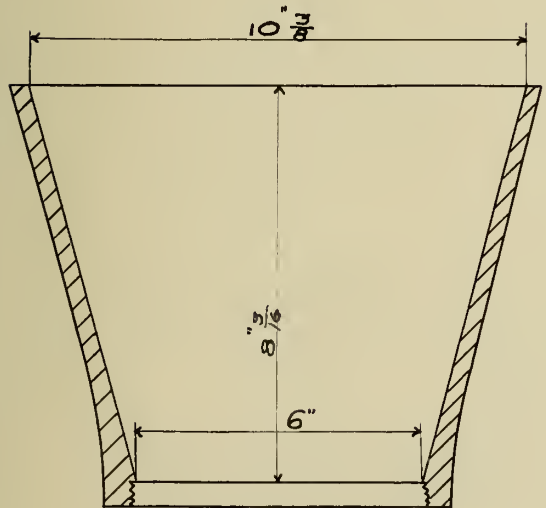
PLATE 2.



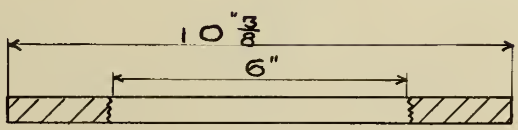
5° – Ratio 1 to 2.



10° – Ratio – 1 to 3.

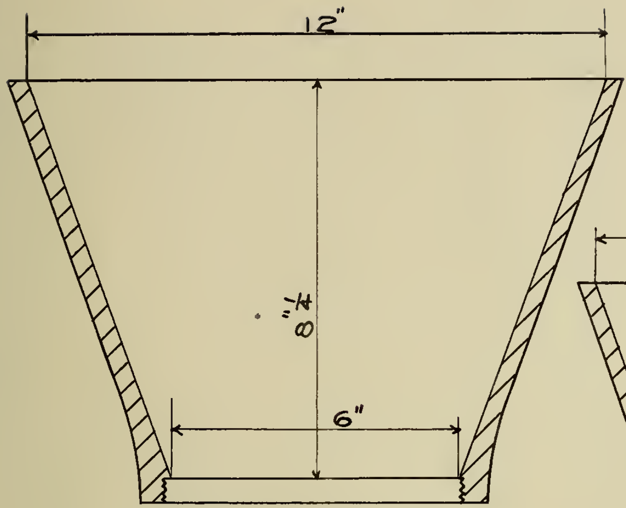


15° Ratio – 1 to 3.

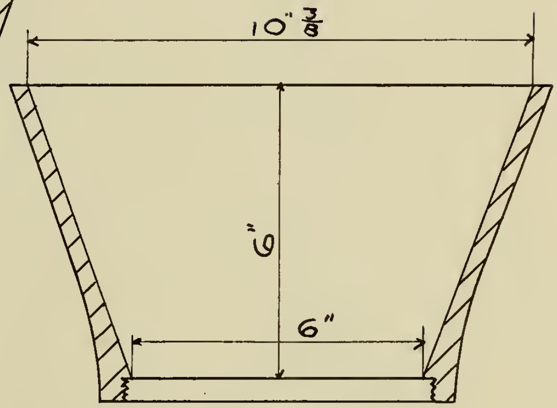


Ring – Ratio – 1 to 3.

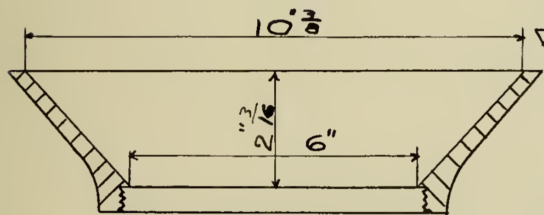
PLATE 3.



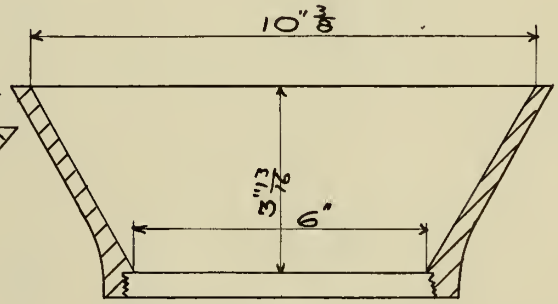
20°- Ratio 1 to 4.



20° Ratio-1 to 3.



45° Ratio. 1 to 3.



30° Ratio 1 to 3.

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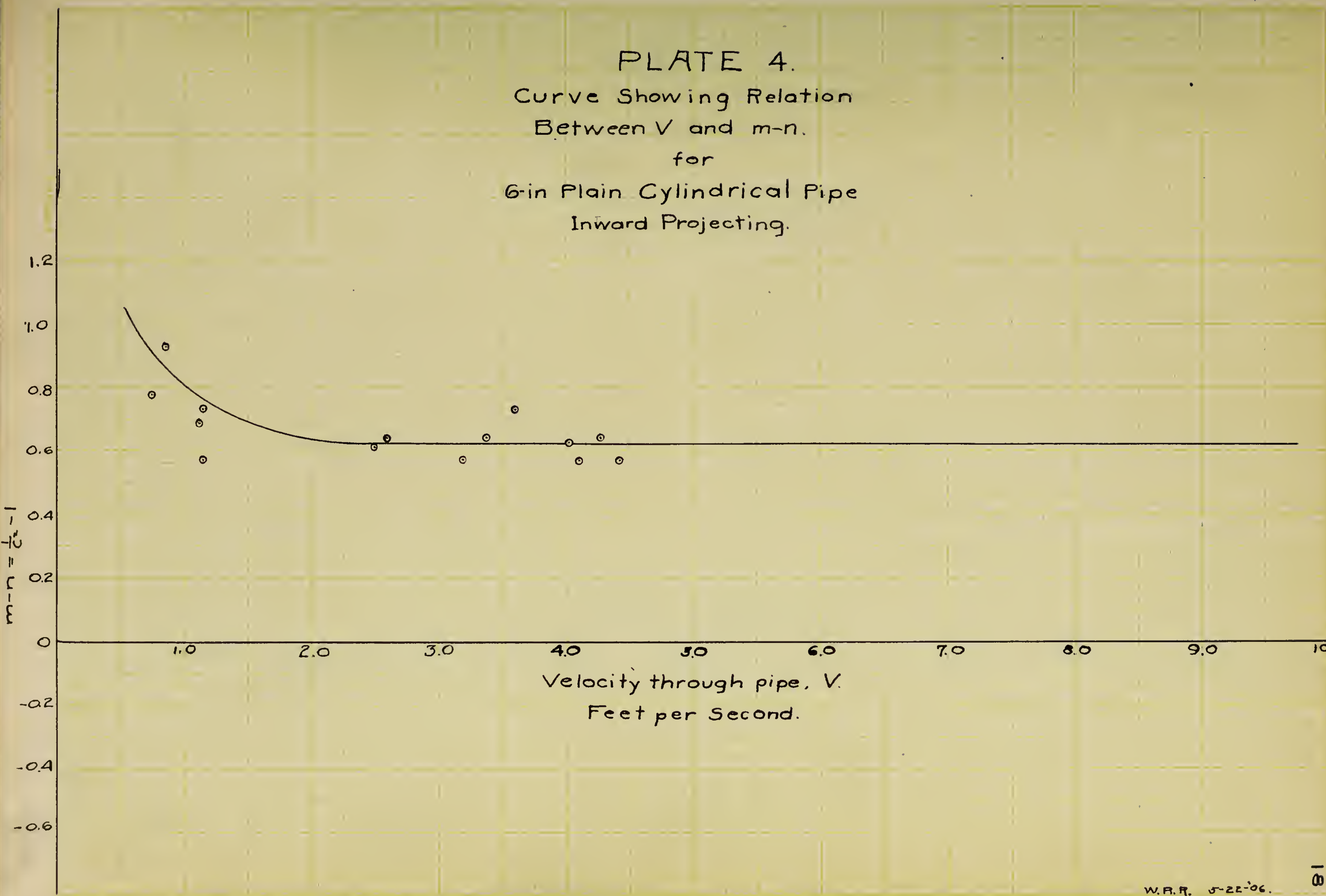


PLATE 4.
Curve Showing Relation
Between V and m-n.
for
6-in Plain Cylindrical Pipe
Inward Projecting.

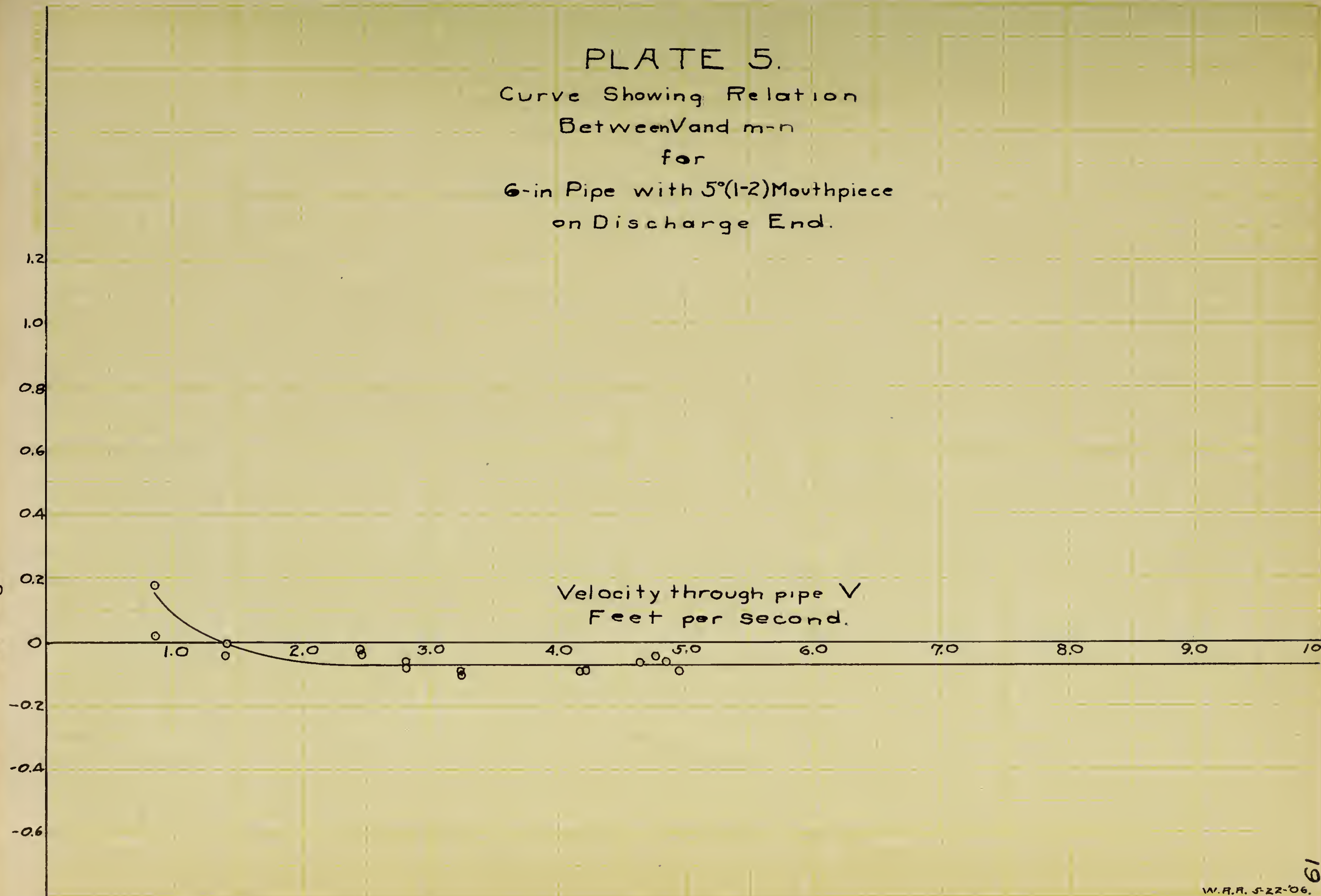


PLATE 5.

Curve Showing Relation
Between V and m-n
for
6-in Pipe with 5°(1-2) Mouthpiece
on Discharge End.

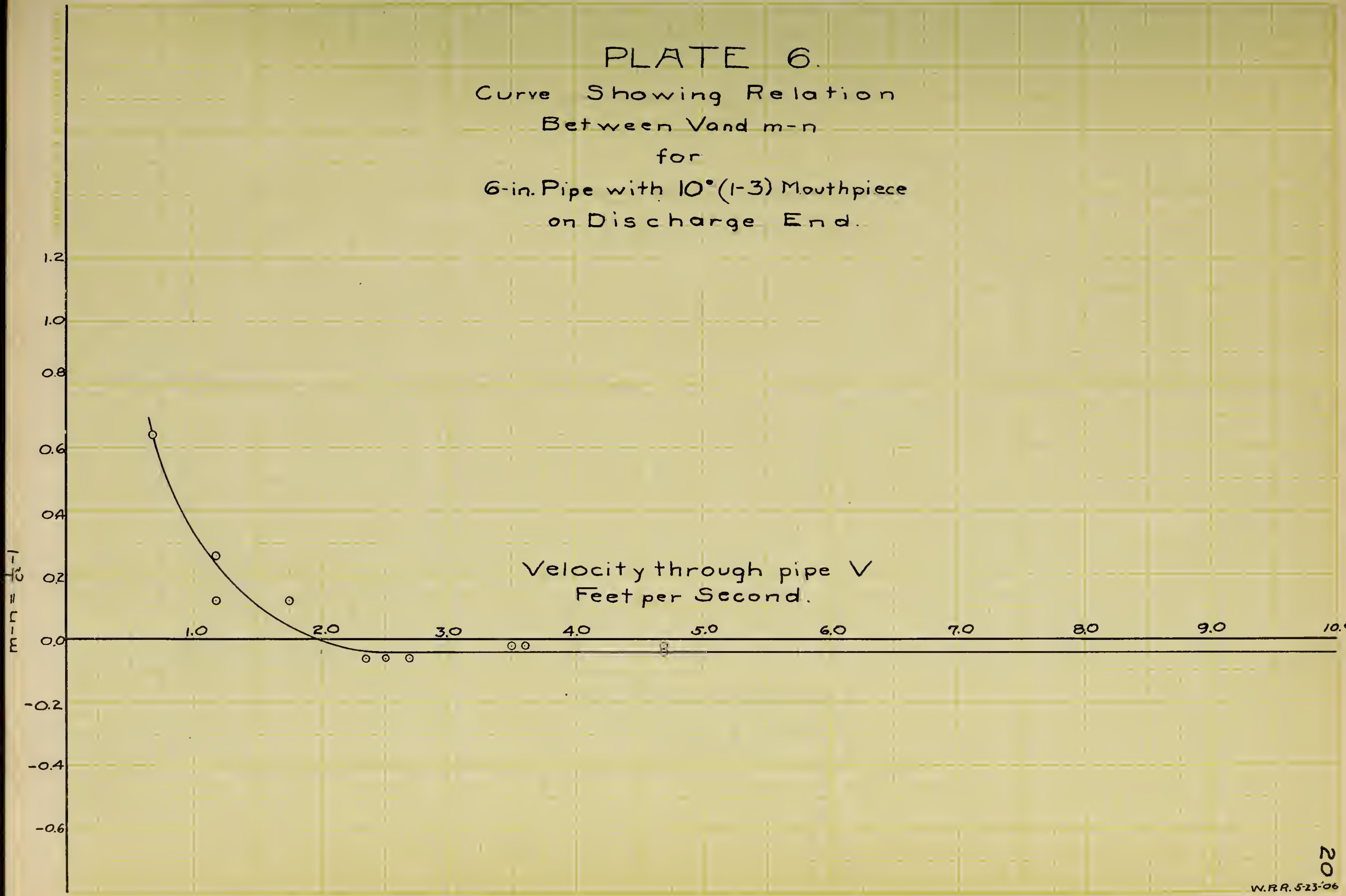


PLATE 6.
Curve Showing Relation
Between V and m-n
for
6-in. Pipe with 10° (1-3) Mouthpiece
on Discharge End.

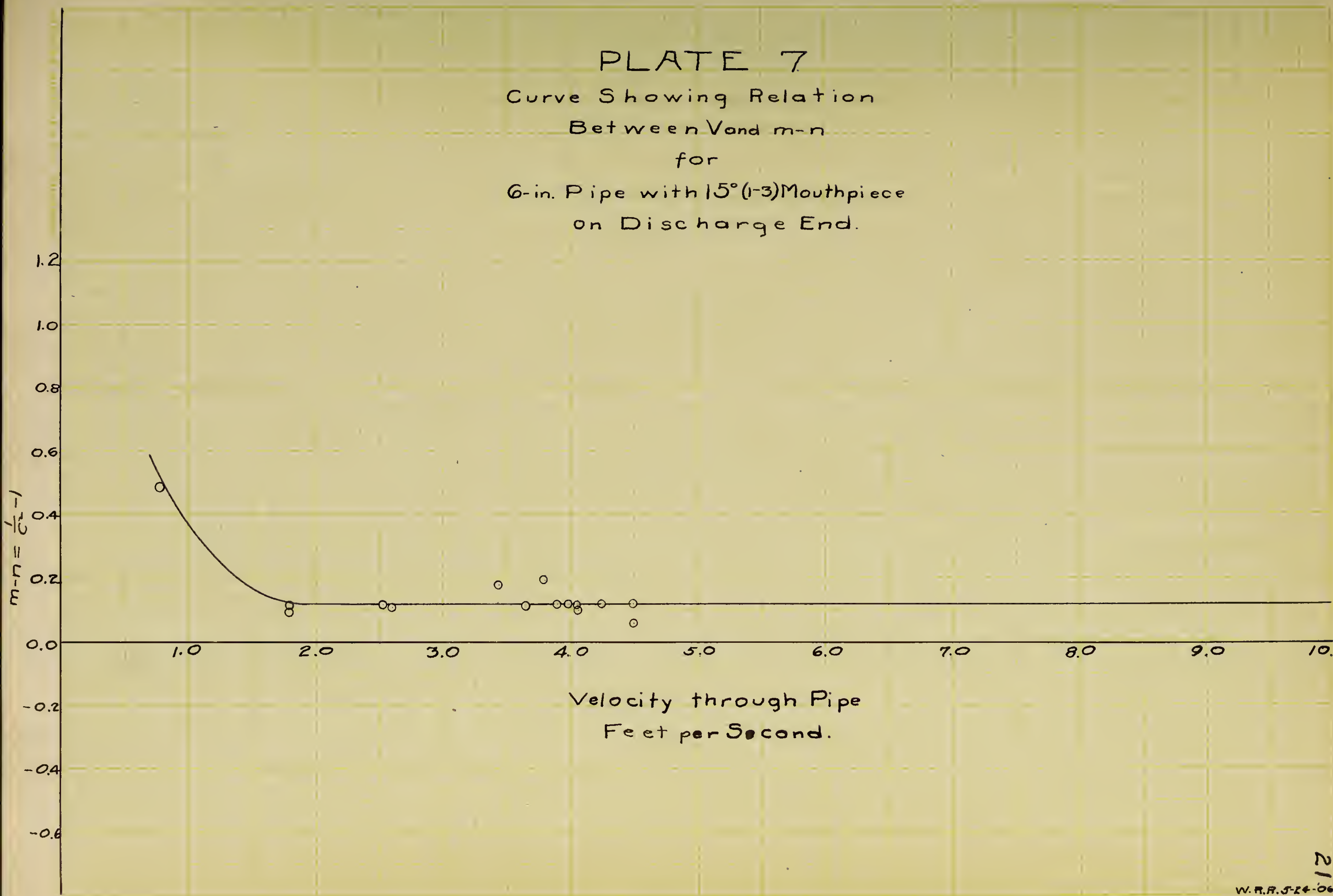


PLATE 7
Curve Showing Relation
Between V and m-n
for
6-in. Pipe with 15° (1-3) Mouthpiece
on Discharge End.

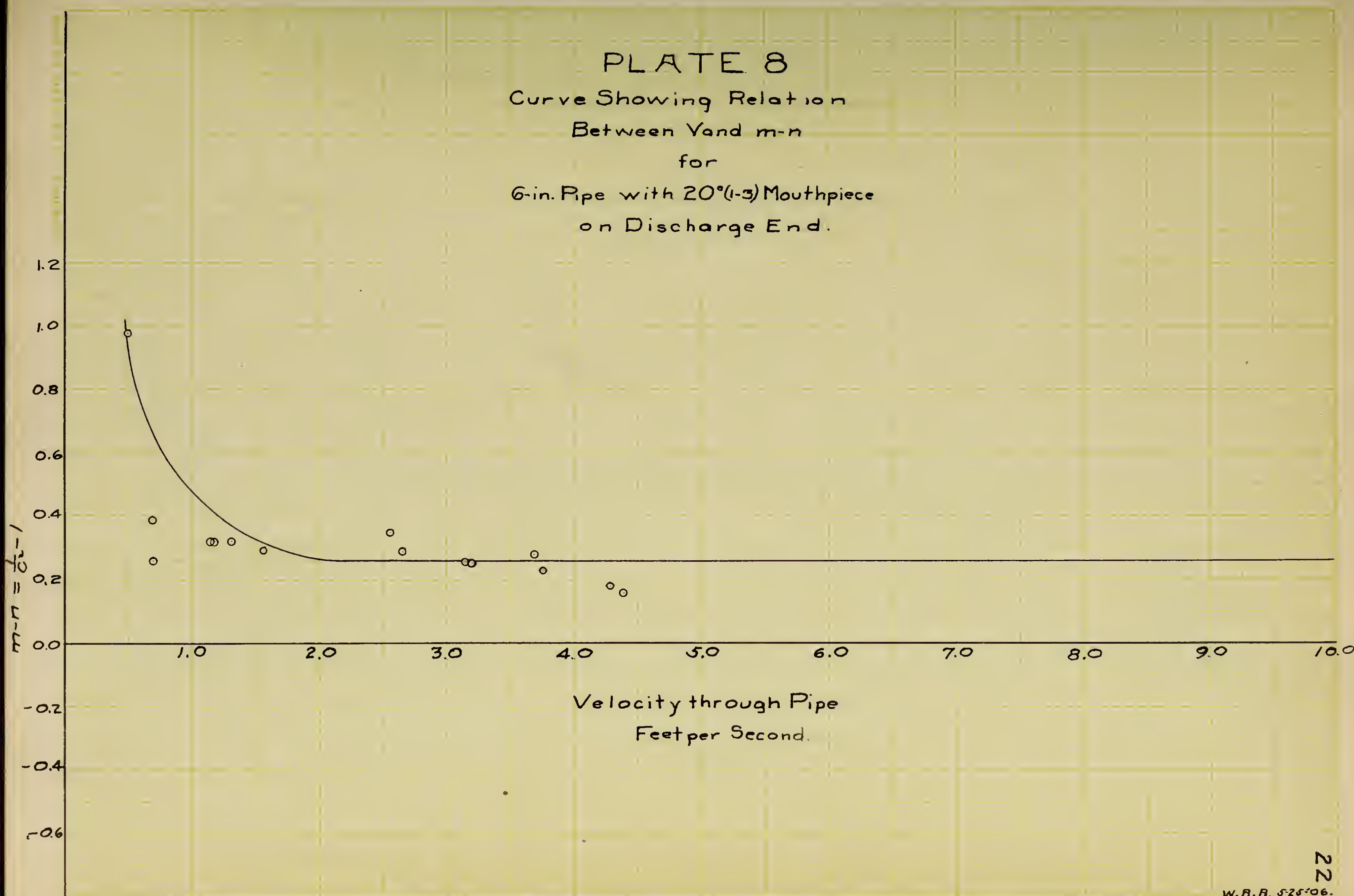


PLATE 8
Curve Showing Relation
Between V and m-n
for
6-in. Pipe with 20°(1-3) Mouthpiece
on Discharge End.
1.2
1.0
0.8
0.6
0.4
0.2
0.0
-0.2
-0.4
-0.6
1.0
2.0
3.0
4.0
5.0
6.0
7.0
8.0
9.0
10.0
Velocity through Pipe
Feet per Second.
22
W.R.R. 5-25-'06.

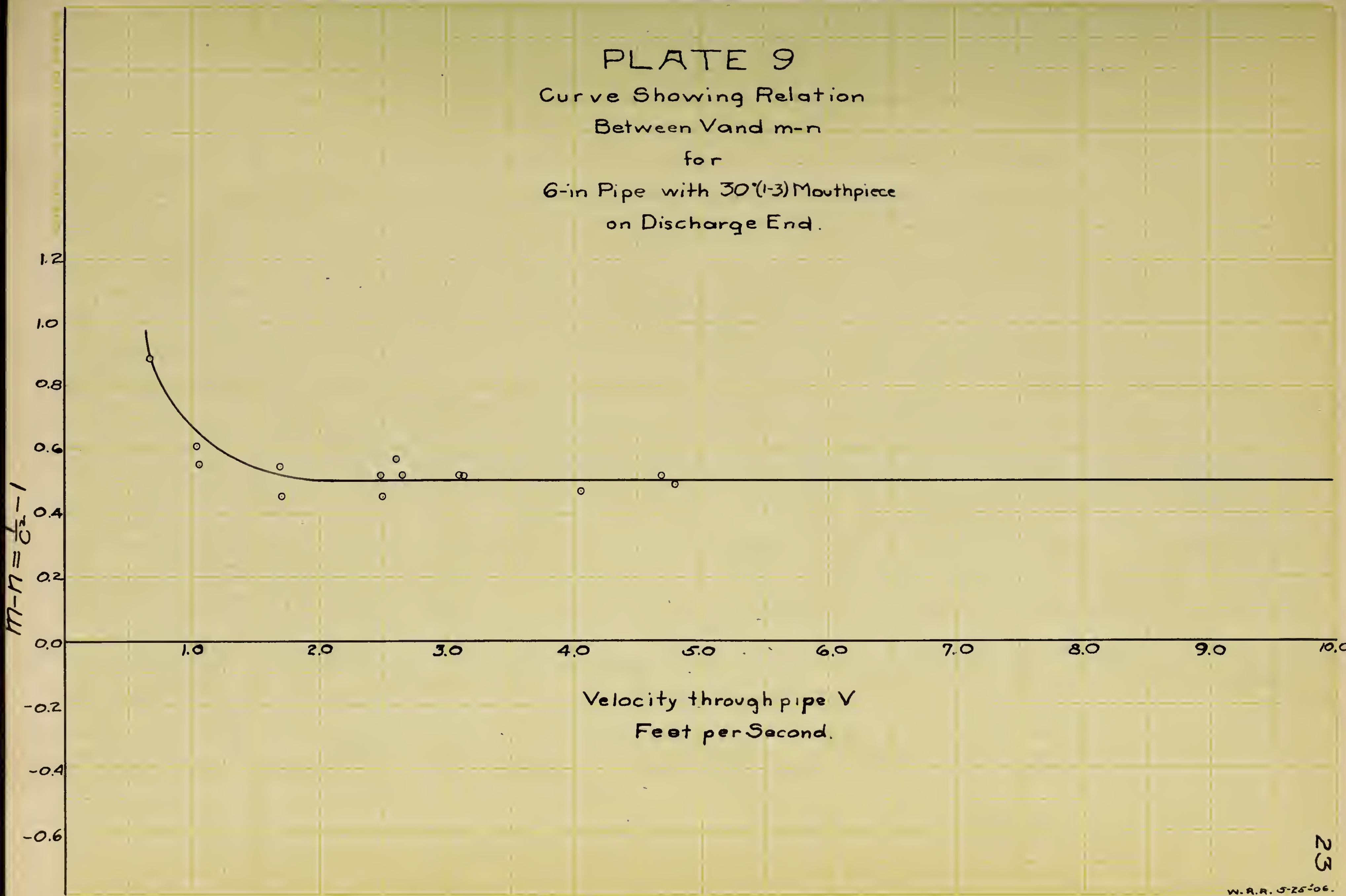


PLATE 9
Curve Showing Relation
Between V and m-n
for
6-in Pipe with 30°(1-3) Mouthpiece
on Discharge End.
$m-n=\frac{1}{c^2}-1$
1.2
1.0
0.8
0.6
0.4
0.2
0.0
-0.2
-0.4
-0.6
1.0
2.0
3.0
4.0
5.0
6.0
7.0
8.0
9.0
10.0
Velocity through pipe V
Feet per Second.
W.R.R. 5-25-06.

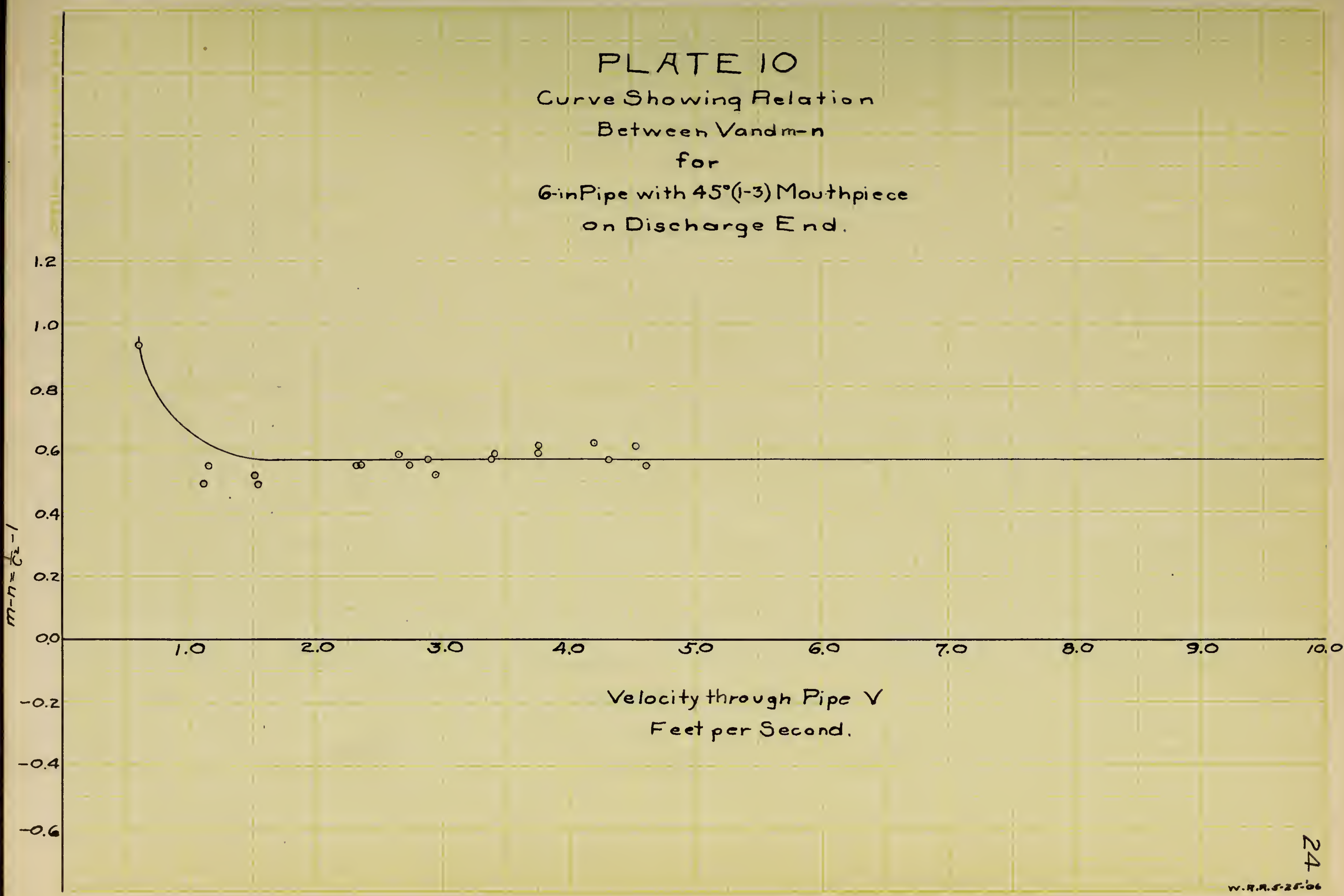


PLATE 10
Curve Showing Relation
Between V and m-n
for
6-in Pipe with 45°(1-3) Mouthpiece
on Discharge End.
1.2
1.0
0.8
0.6
0.4
0.2
0.0
-0.2
-0.4
-0.6
$m-n=\frac{1}{C_2}-1$
1.0
2.0
3.0
4.0
5.0
6.0
7.0
8.0
9.0
10.0
Velocity through Pipe V
Feet per Second.
24
W.R.R. 5-25-'06

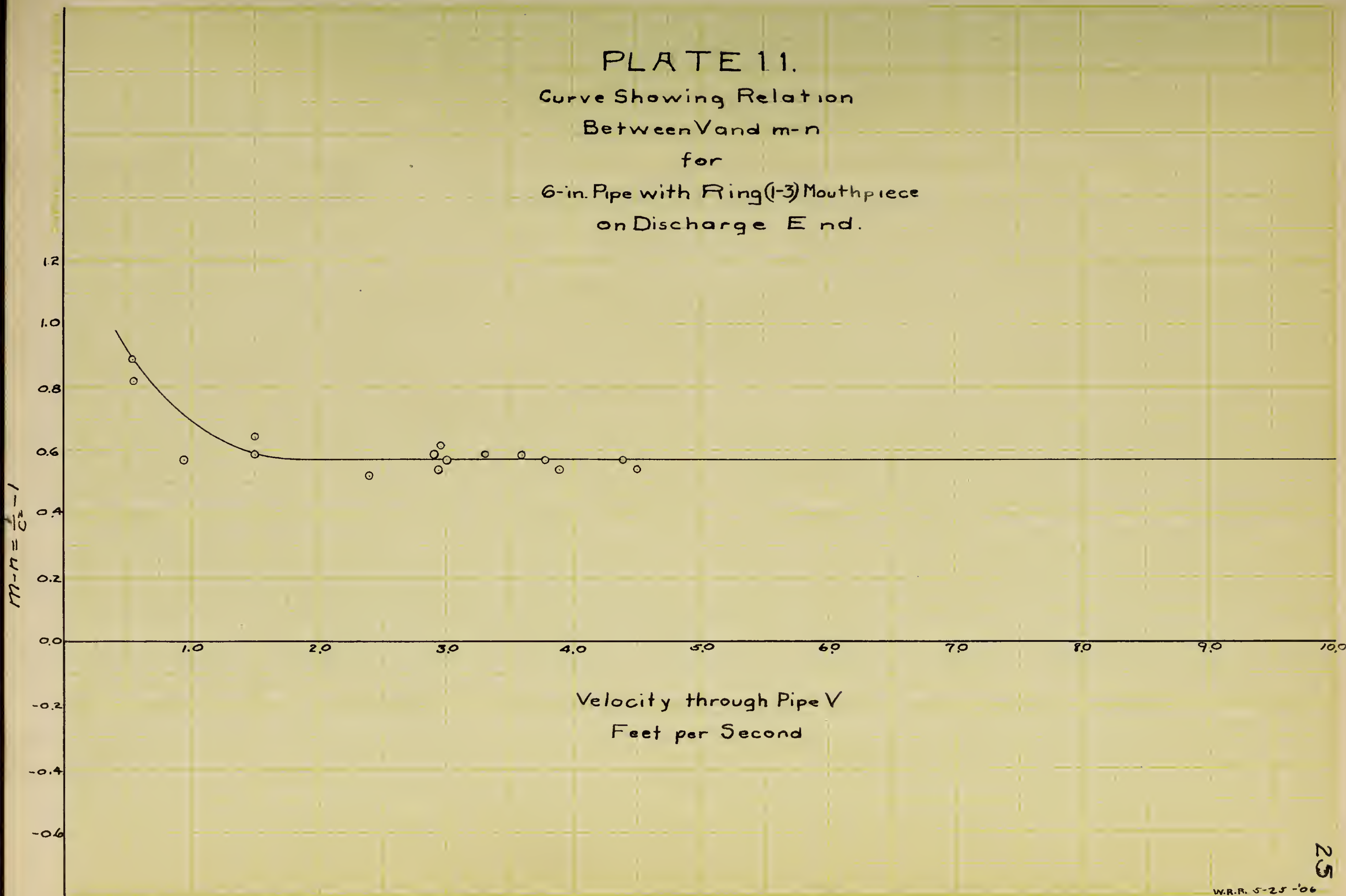
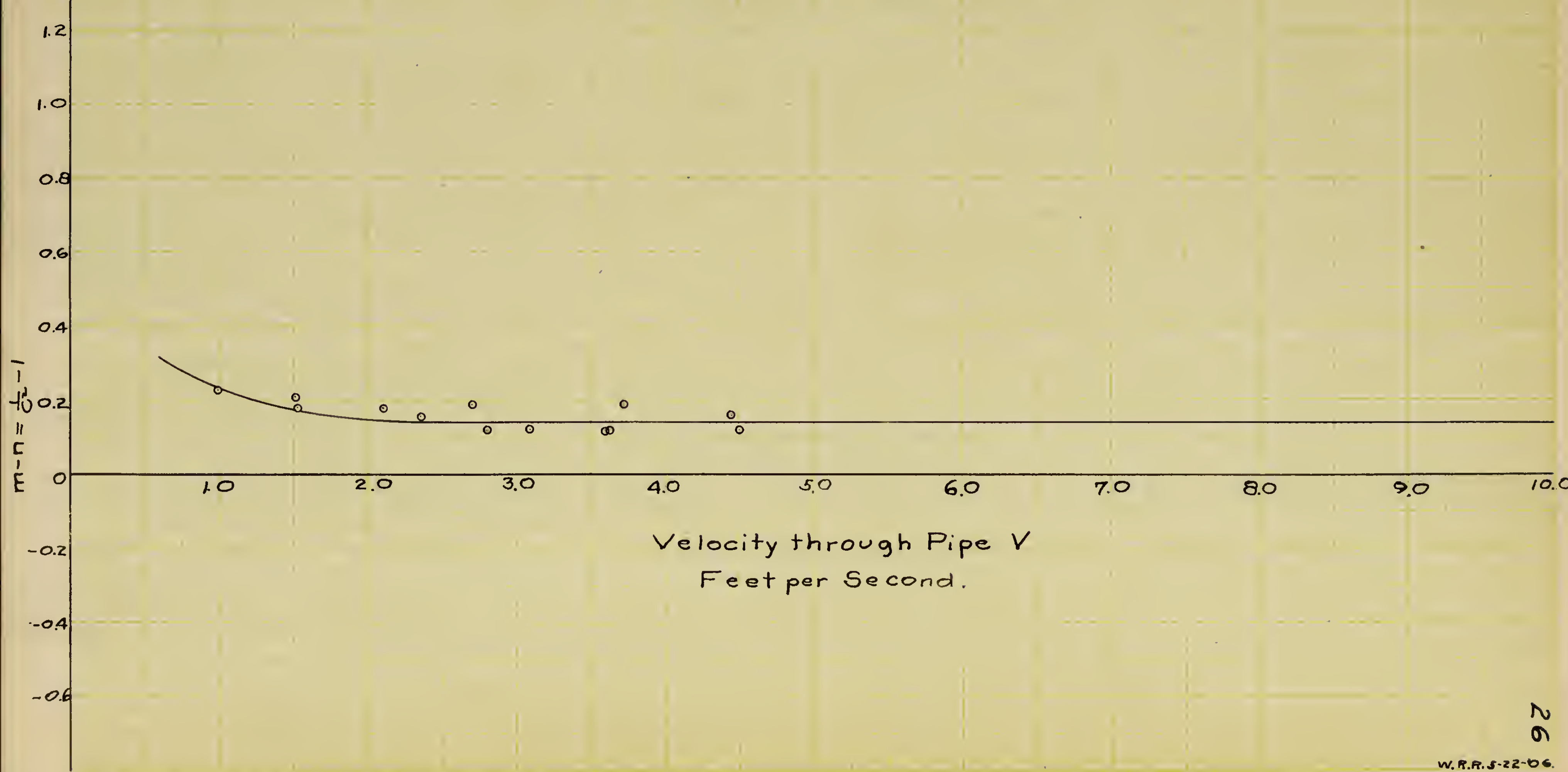


PLATE 11.
Curve Showing Relation
Between V and m-n
for
6-in. Pipe with Ring (1-3) Mouthpiece
on Discharge End.
1.2
1.0
0.8
0.6
0.4
0.2
0.0
-0.2
-0.4
-0.6
$m-n=\frac{1}{c^2}-1$
1.0
2.0
3.0
4.0
5.0
6.0
7.0
8.0
9.0
10.0
Velocity through Pipe V
Feet per Second
W.R.R. 5-25-'06

PLATE 12

Curve Showing Relation
Between V and m-n
for
6-in Pipe with 20°(1-3) Inlet Mouthpiece.



W.R.R. 5-22-'06.

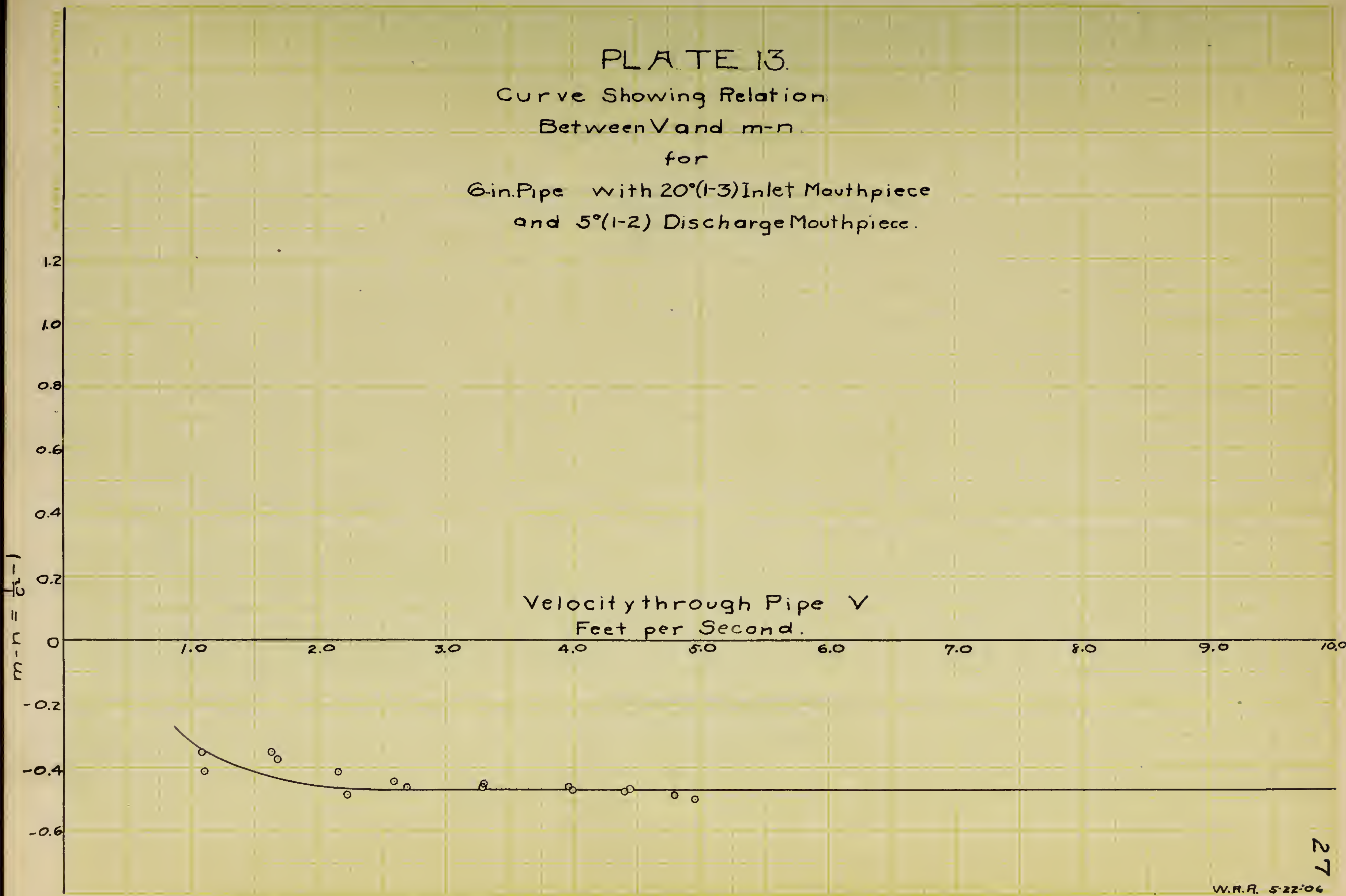
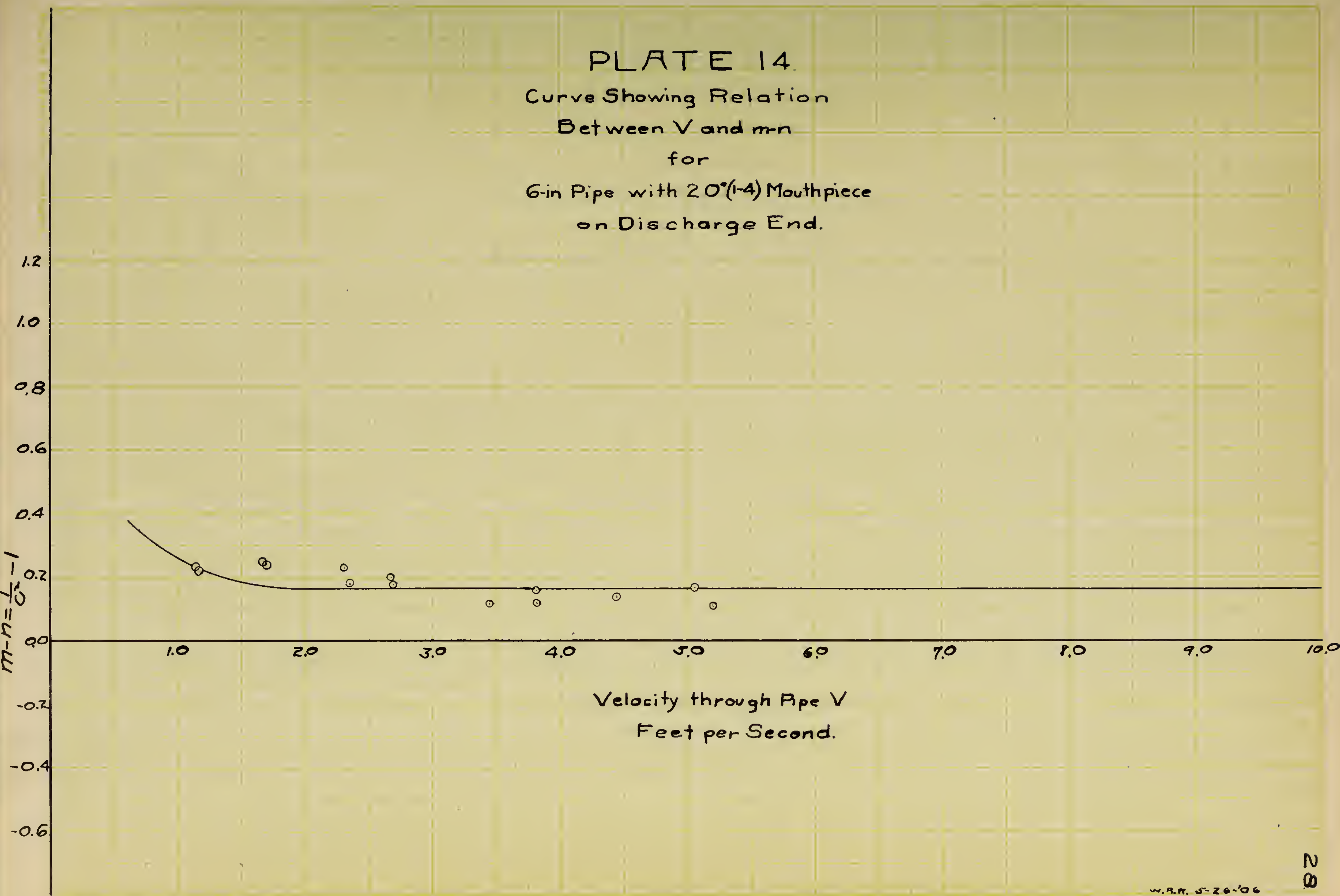


PLATE 13.
Curve Showing Relation
Between V and m-n
for
6-in. Pipe with 20°(1-3) Inlet Mouthpiece
and 5°(1-2) Discharge Mouthpiece.
Velocity through Pipe V
Feet per Second.
$m-n = \frac{1}{c^2}-1$
1.2
1.0
0.8
0.6
0.4
0.2
0
-0.2
-0.4
-0.6
1.0
2.0
3.0
4.0
5.0
6.0
7.0
8.0
9.0
10.0
W.R.R. 5-22-06

PLATE 14

Curve Showing Relation
Between V and m-n
for
6-in Pipe with 20°(1-4) Mouthpiece
on Discharge End.



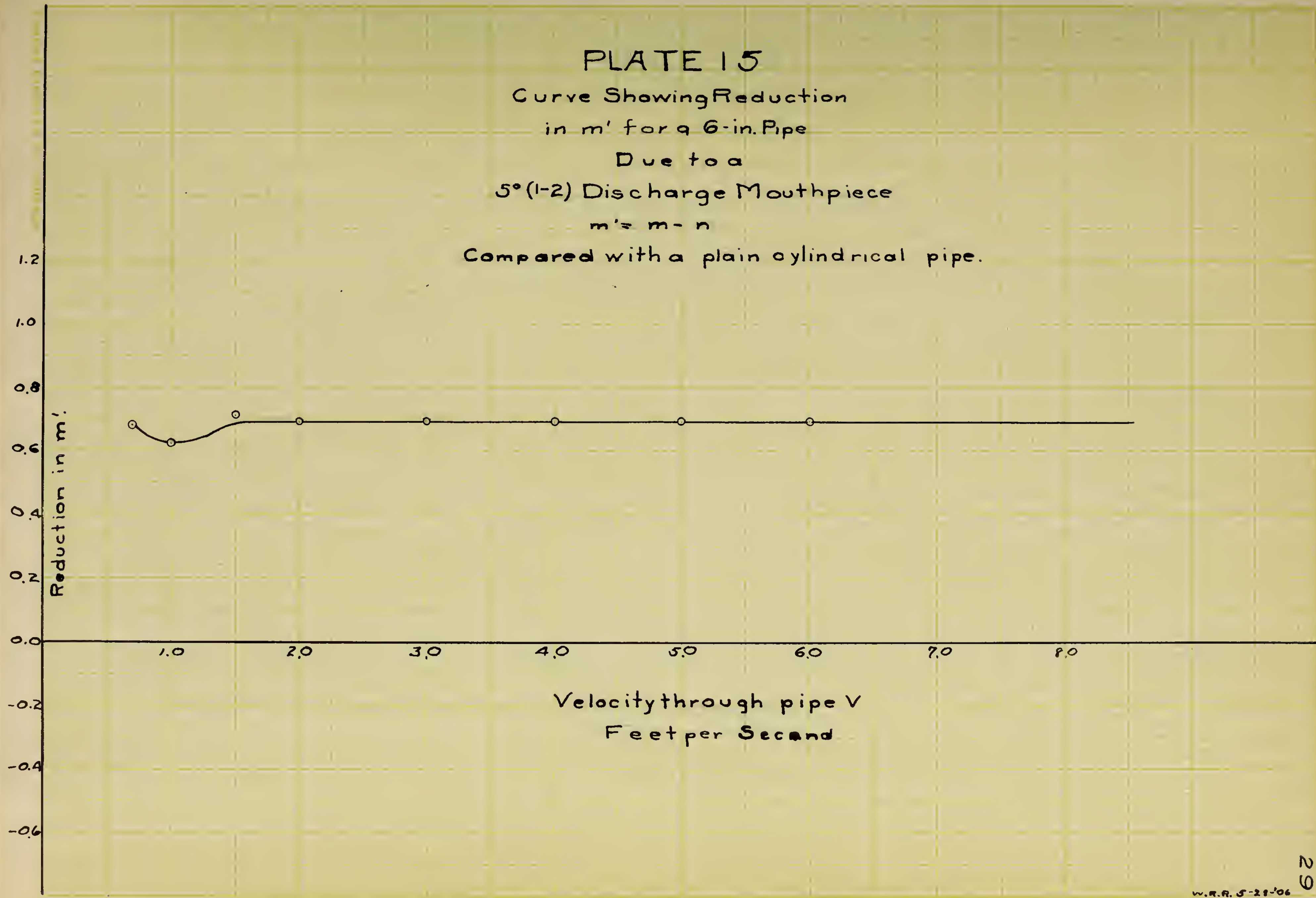


PLATE 15
Curve Showing Reduction
in m' for a 6-in. Pipe
Due to a
5°(1-2) Discharge Mouthpiece
m' = m - n
Compared with a plain cylindrical pipe.
Reduction in m'
1.2
1.0
0.8
0.6
0.4
0.2
0.0
-0.2
-0.4
-0.6
1.0
2.0
3.0
4.0
5.0
6.0
7.0
8.0
Velocity through pipe V
Feet per Second
W.R.R. 5-28-'06

PLATE 16

Curve Showing Reduction
in m' for a 6-in. Pipe
Due to a
10°(1-3) Discharge Mouthpiece
$m' = m - n$
Compared with a plain cylindrical pipe.

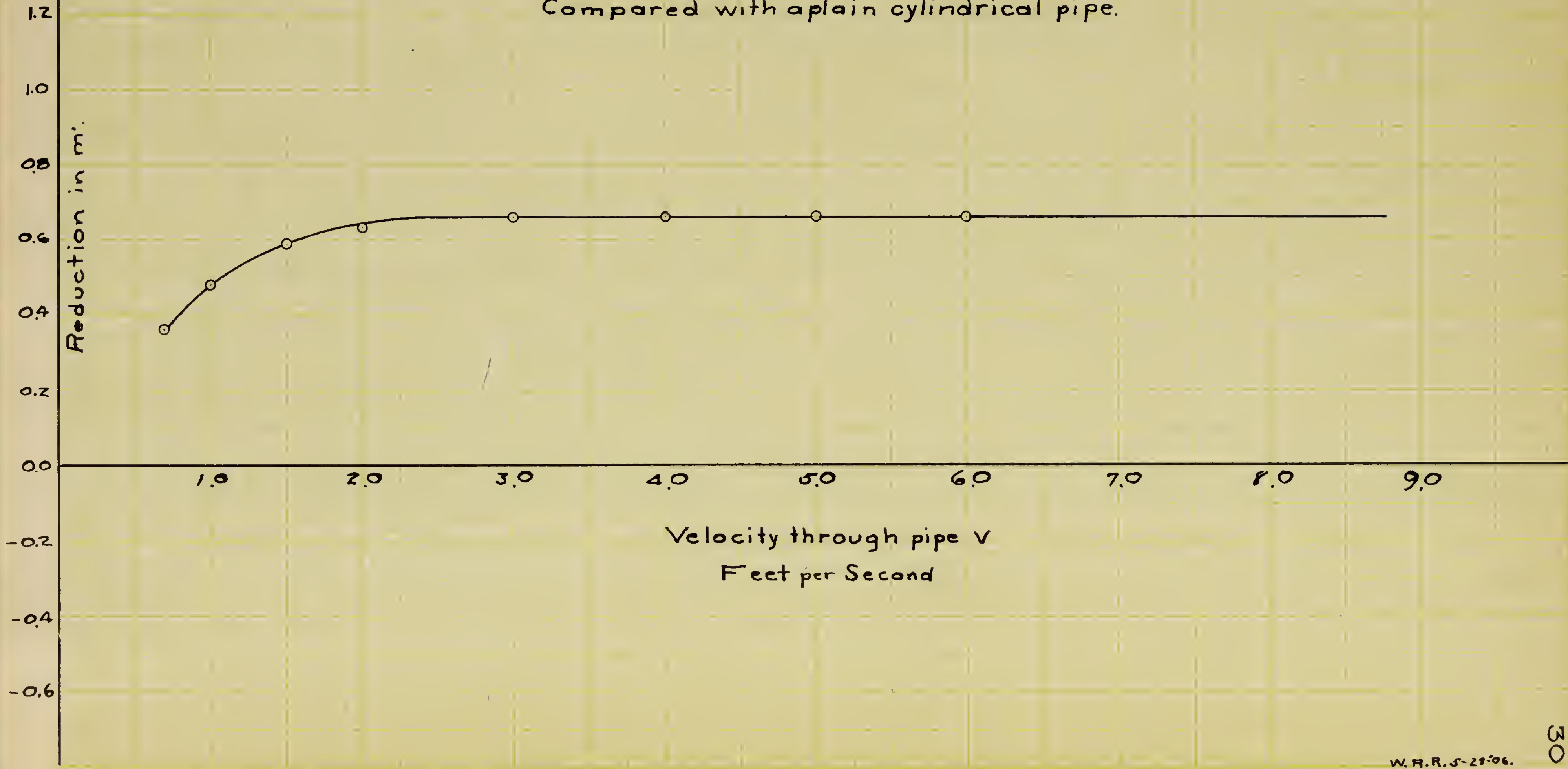
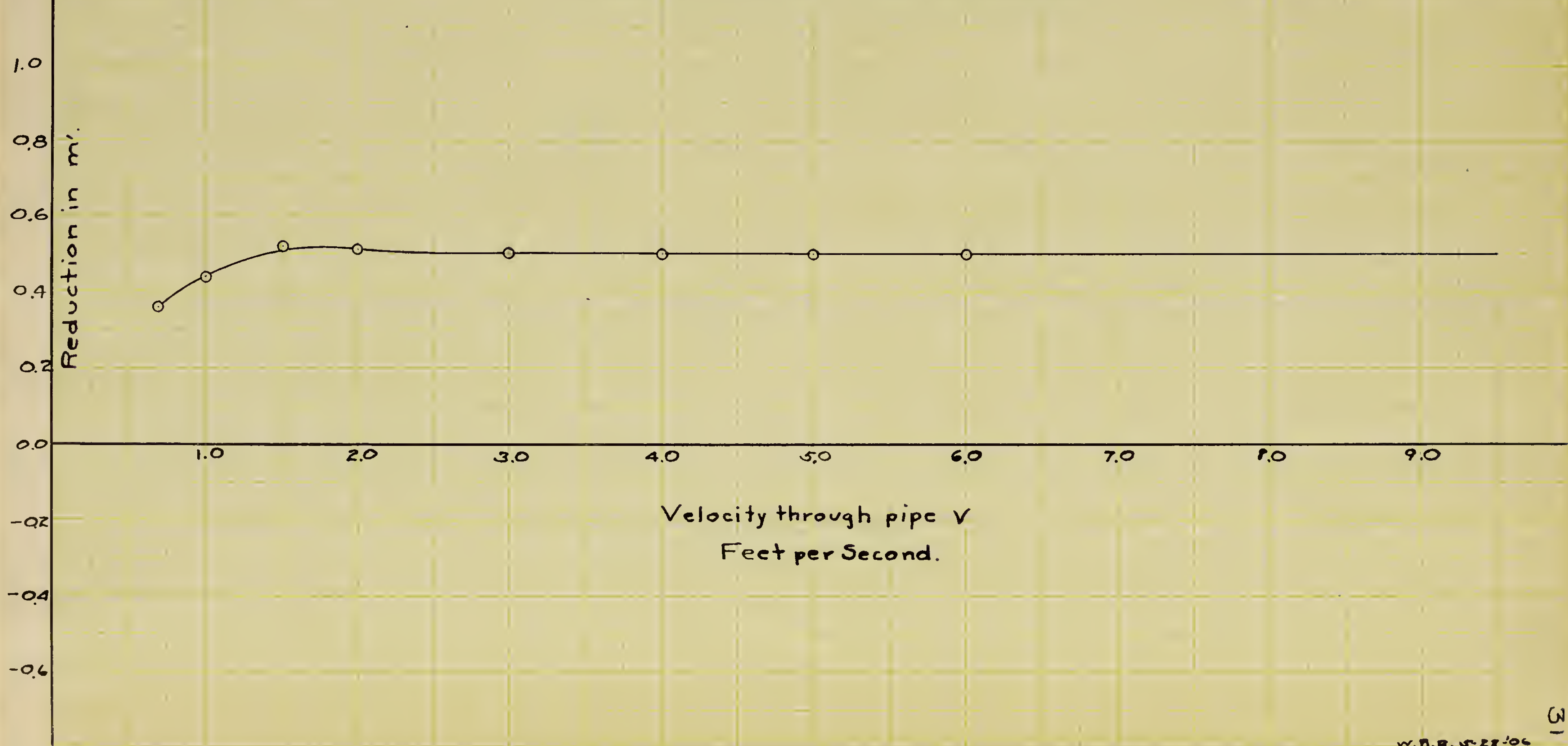


PLATE 17.

Curve Showing Reduction
in m' for a 6-in Pipe
Due to a
15°(1-3) Discharge Mouthpiece.
$m' = m - n$
Compared with a plain cylindrical pipe.



W.R.R. 5-28-'06

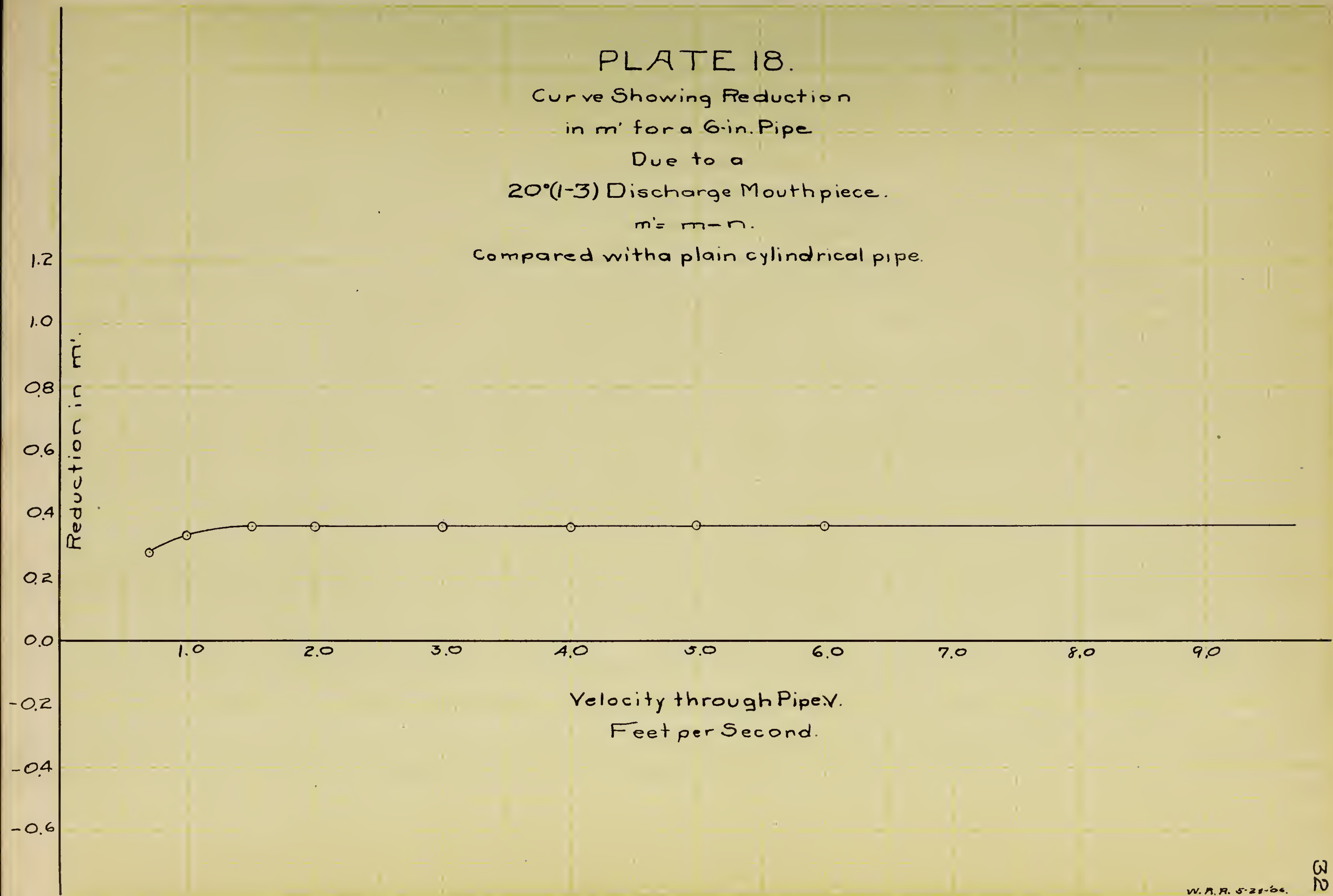


PLATE 18.

Curve Showing Reduction in m' for a 6-in. Pipe Due to a 20°(1-3) Discharge Mouthpiece.

$m' = m - n$.

Compared with a plain cylindrical pipe.

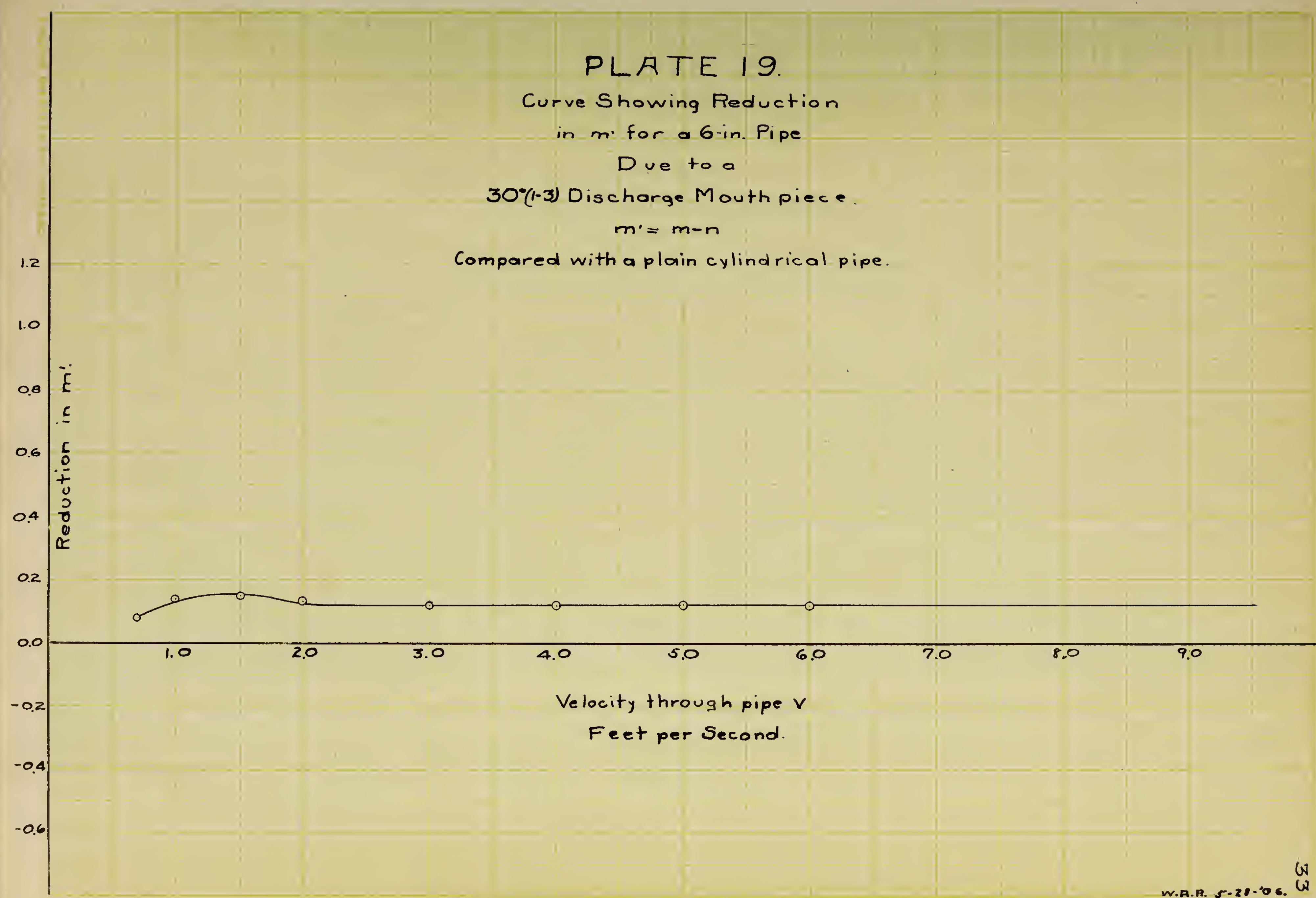


PLATE 19.
Curve Showing Reduction
in m' for a 6-in. Pipe
Due to a
30°(1-3) Discharge Mouth piece.
m' = m-n
Compared with a plain cylindrical pipe.
Reduction in m'.
1.2
1.0
0.8
0.6
0.4
0.2
0.0
-0.2
-0.4
-0.6
1.0
2.0
3.0
4.0
5.0
6.0
7.0
8.0
9.0
Velocity through pipe V
Feet per Second.
W.R.R. 5-28-'06.

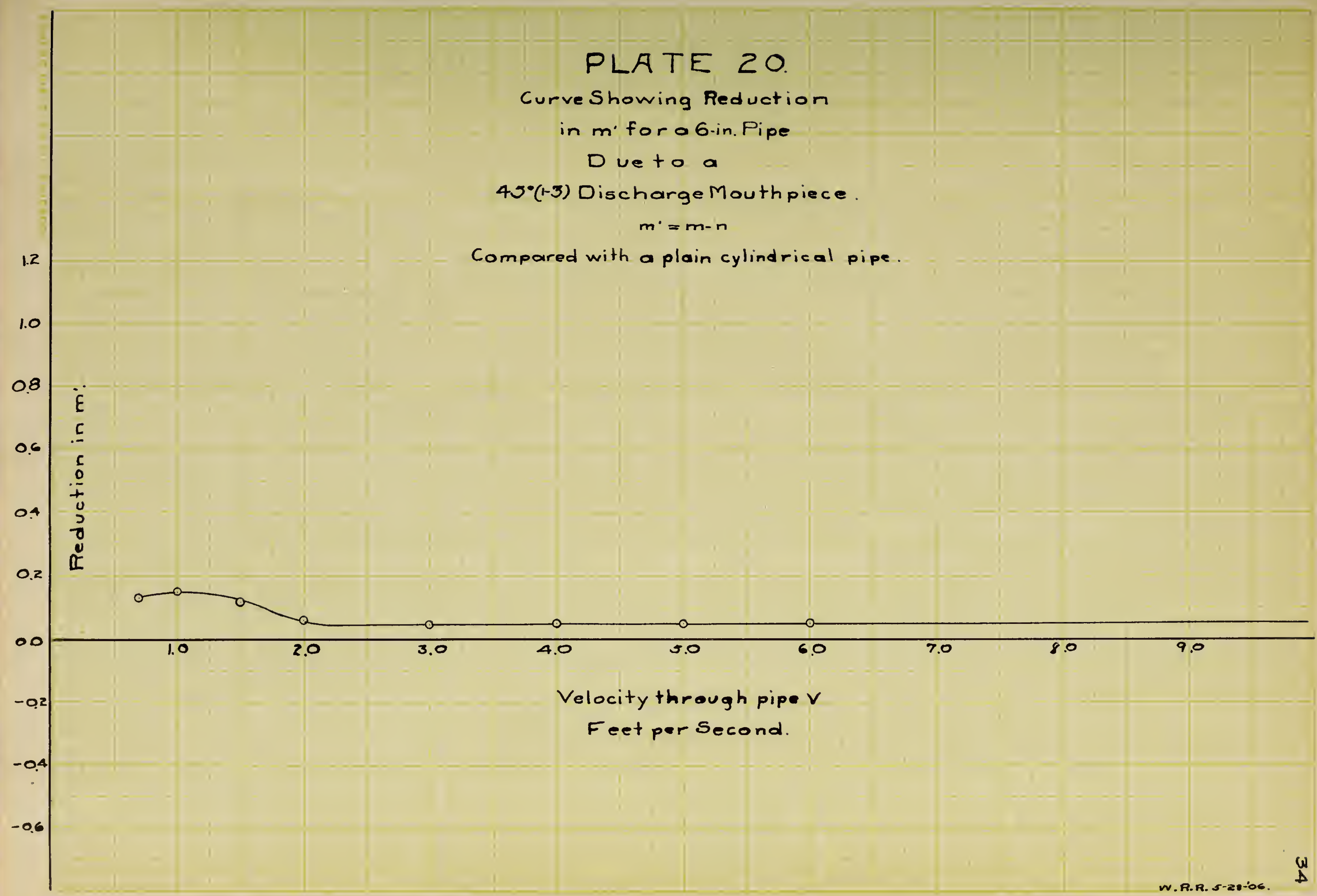


PLATE 20.
Curve Showing Reduction
in m' for a 6-in. Pipe
Due to a
45°(1-3) Discharge Mouthpiece.
m' = m-n
Compared with a plain cylindrical pipe.
Reduction in m'.
1.2
1.0
0.8
0.6
0.4
0.2
0.0
-0.2
-0.4
-0.6
1.0
2.0
3.0
4.0
5.0
6.0
7.0
8.0
9.0
Velocity through pipe V
Feet per Second.
W.R.R. 5-28-'06.
34

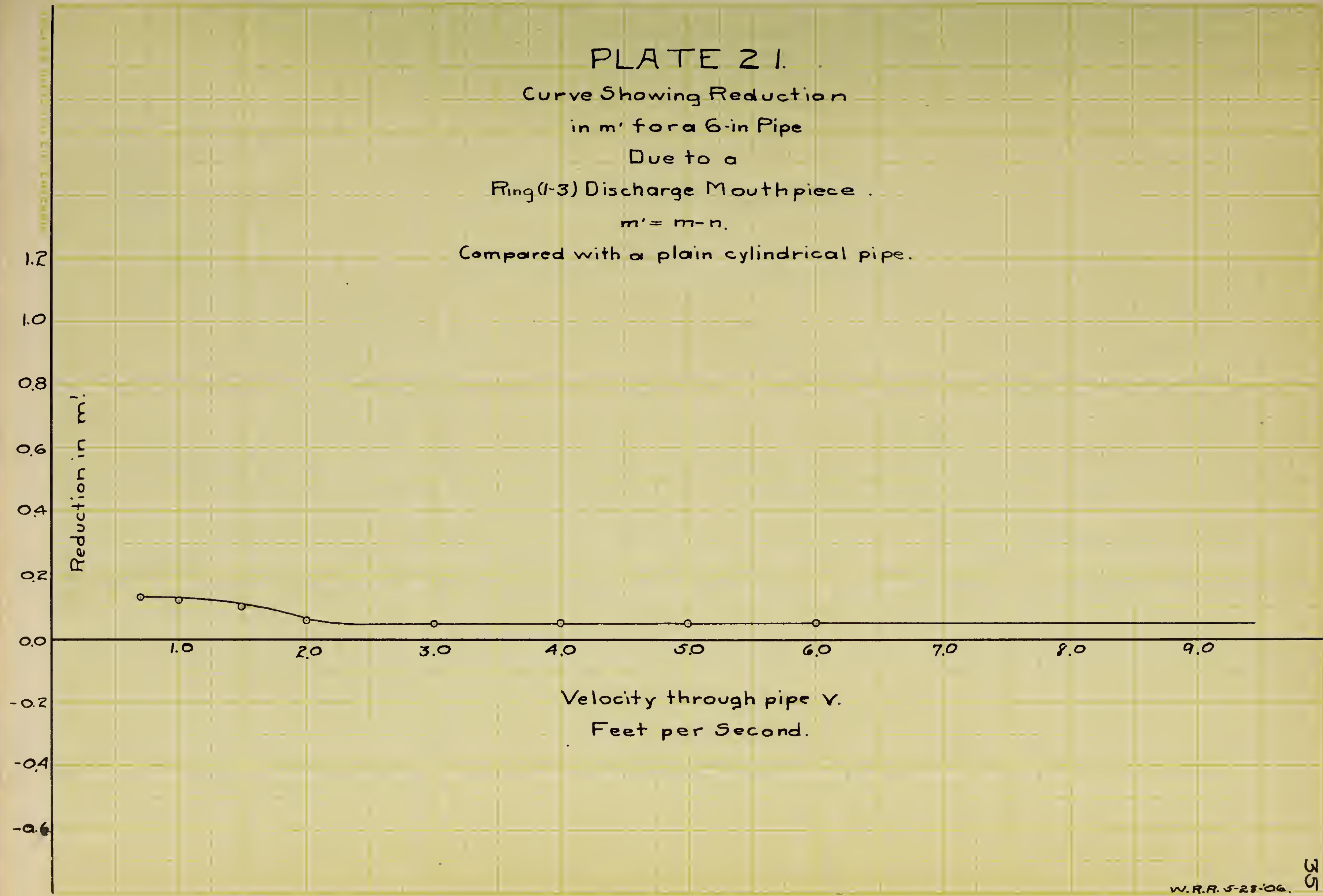


PLATE 21.
Curve Showing Reduction
in m' for a 6-in Pipe
Due to a
Ring (1-3) Discharge Mouthpiece.
m' = m - n.
Compared with a plain cylindrical pipe.
Reduction in m'.
1.2
1.0
0.8
0.6
0.4
0.2
0.0
-0.2
-0.4
-0.6
1.0
2.0
3.0
4.0
5.0
6.0
7.0
8.0
9.0
Velocity through pipe V.
Feet per Second.
W.R.R. 5-28-'06.


PLATE 22.
Curve Showing Reduction
in m' for a 6-in. Pipe
Due to a
20°(1-3) Inlet Mouthpiece
m' = m - n.
Compared with a plain cylindrical pipe.
1.2
1.0
0.8
0.6
0.4
0.2
0.0
-0.2
-0.4
-0.6
Reduction in m'.
1.0
2.0
3.0
4.0
5.0
6.0
7.0
8.0
9.0
Velocity through pipe V.
Feet per Second.
W.R.A. 07-25-06

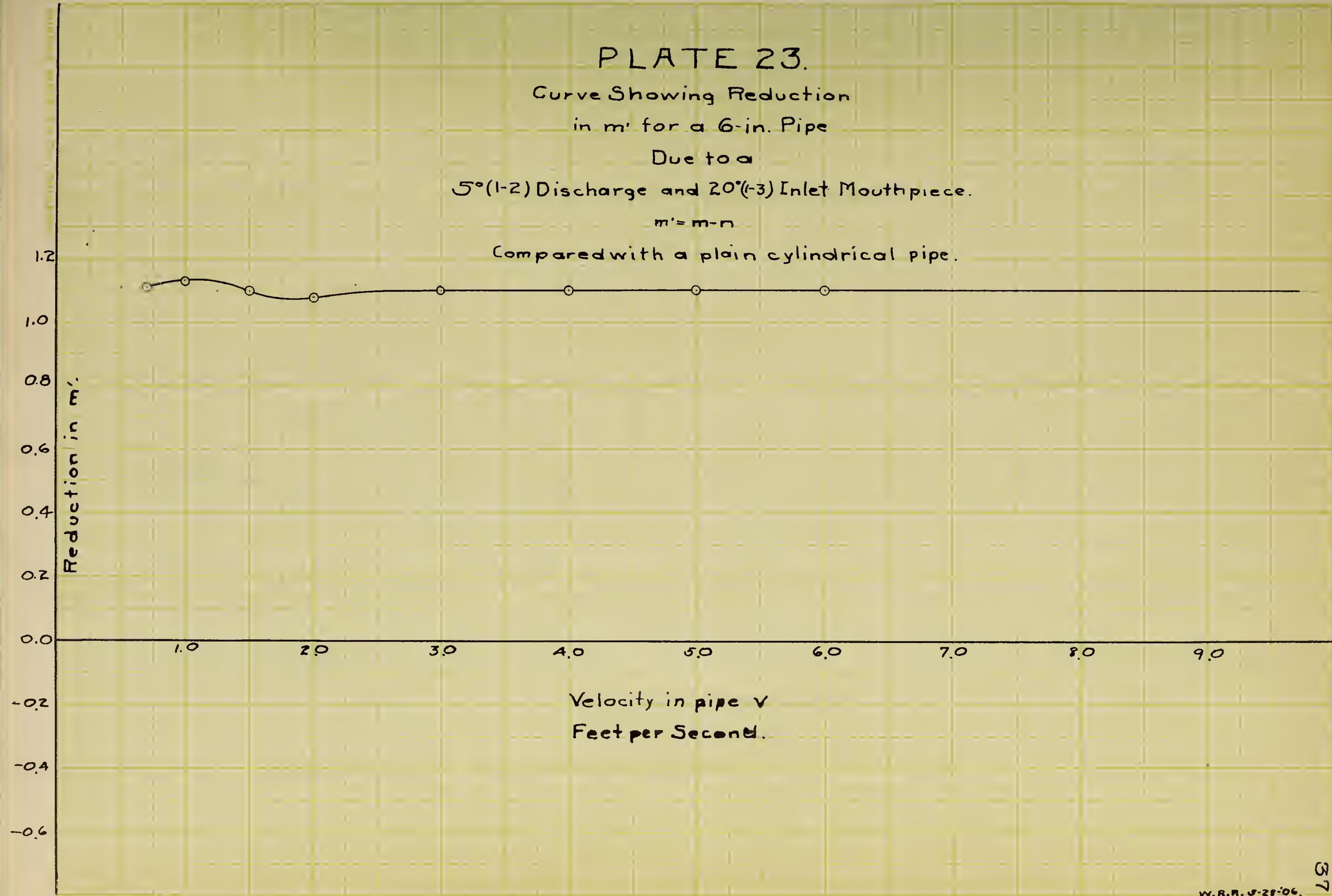


PLATE 23.
Curve Showing Reduction
in m' for a 6-in. Pipe
Due to a
5°(1-2) Discharge and 20°(1-3) Inlet Mouthpiece.
m' = m-n
Compared with a plain cylindrical pipe.
Reduction in m'.
1.2
1.0
0.8
0.6
0.4
0.2
0.0
-0.2
-0.4
-0.6
1.0
2.0
3.0
4.0
5.0
6.0
7.0
8.0
9.0
Velocity in pipe V
Feet per Second.
W.R.R. 5-28-'06.

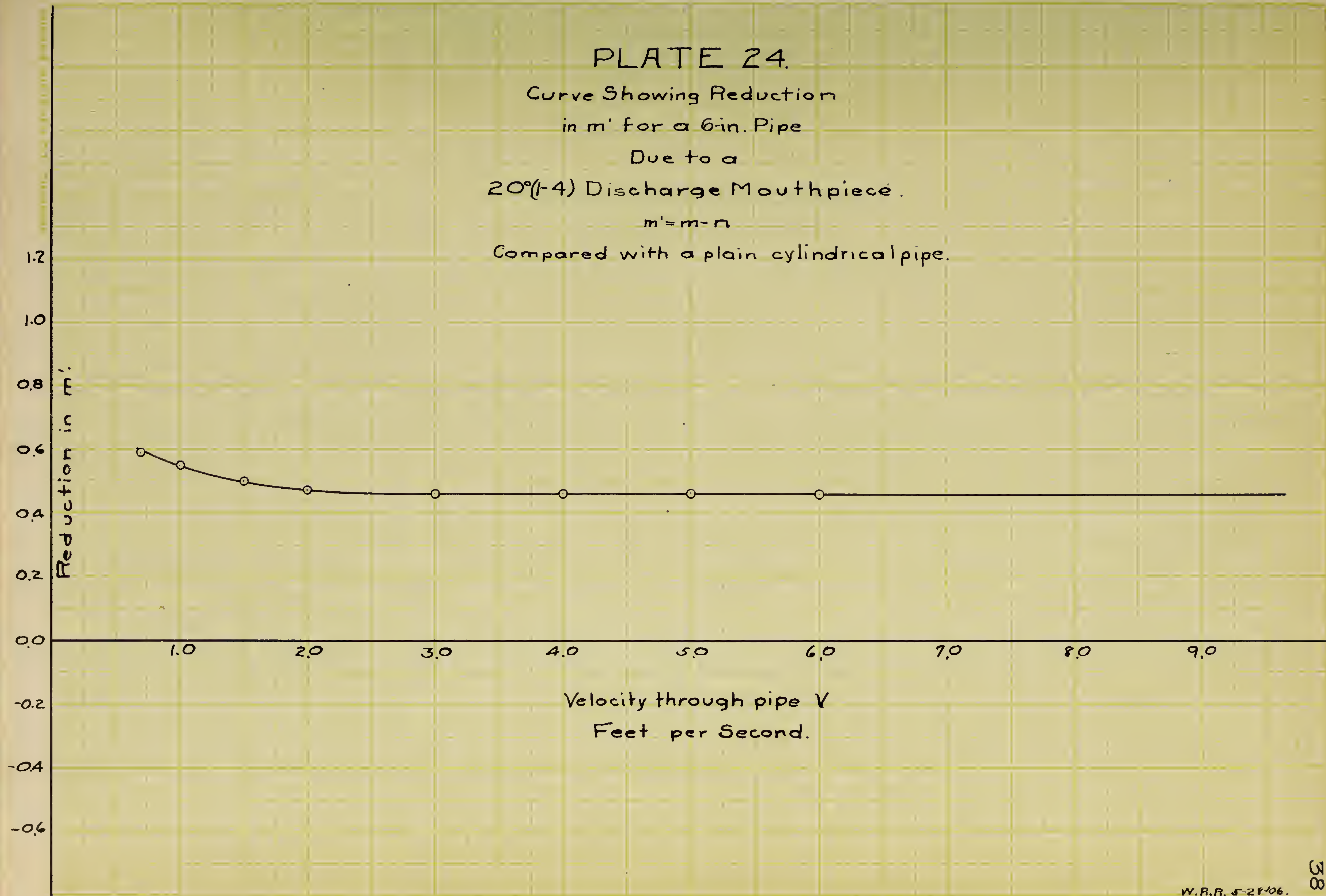


PLATE 24.
Curve Showing Reduction
in m' for a 6-in. Pipe
Due to a
20°(1-4) Discharge Mouthpiece.
m'=m-n
Compared with a plain cylindrical pipe.
Reduction in m'.
1.2
1.0
0.8
0.6
0.4
0.2
0.0
-0.2
-0.4
-0.6
1.0
2.0
3.0
4.0
5.0
6.0
7.0
8.0
9.0
Velocity through pipe V
Feet per Second.
W.R.R. 5-28-06.

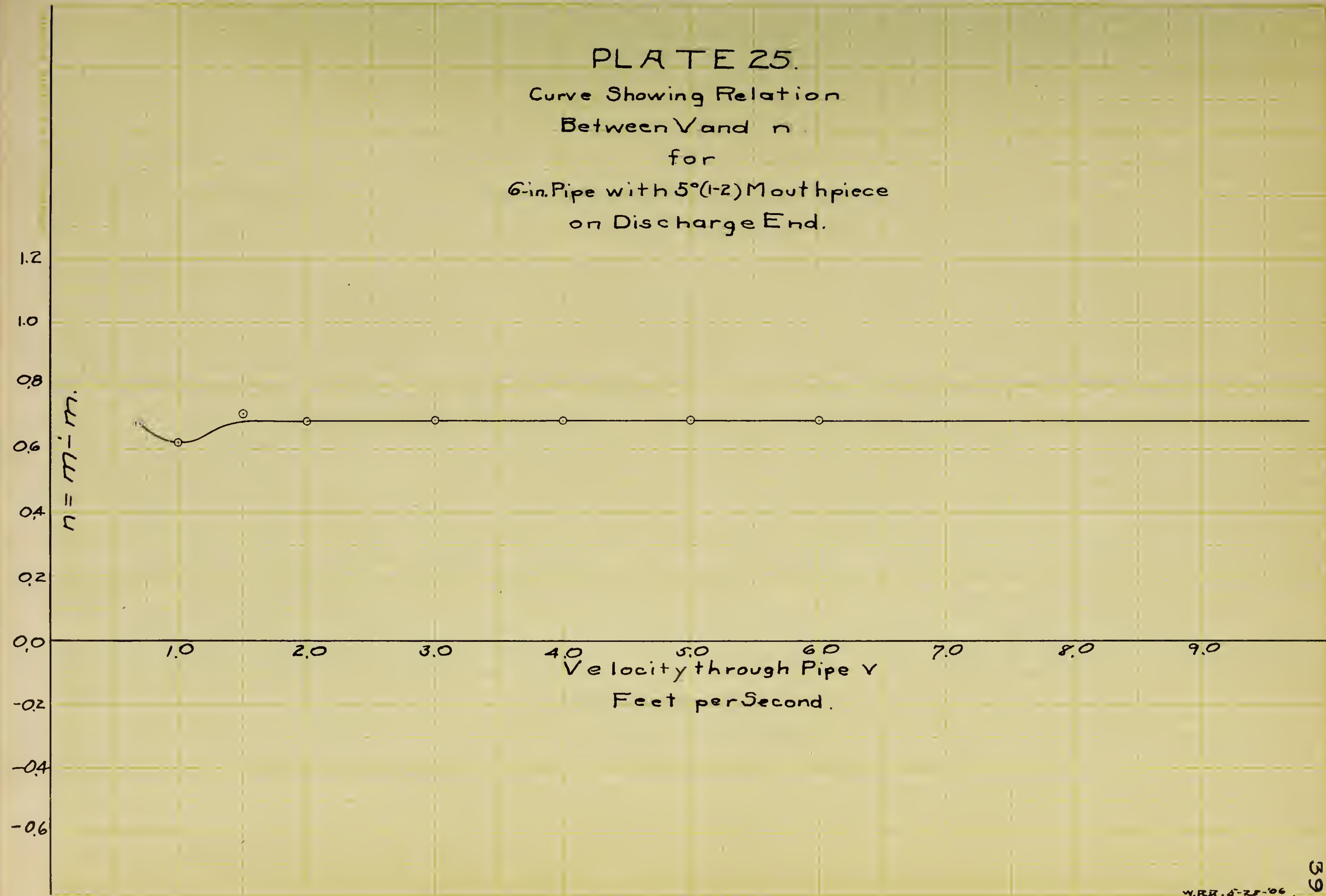
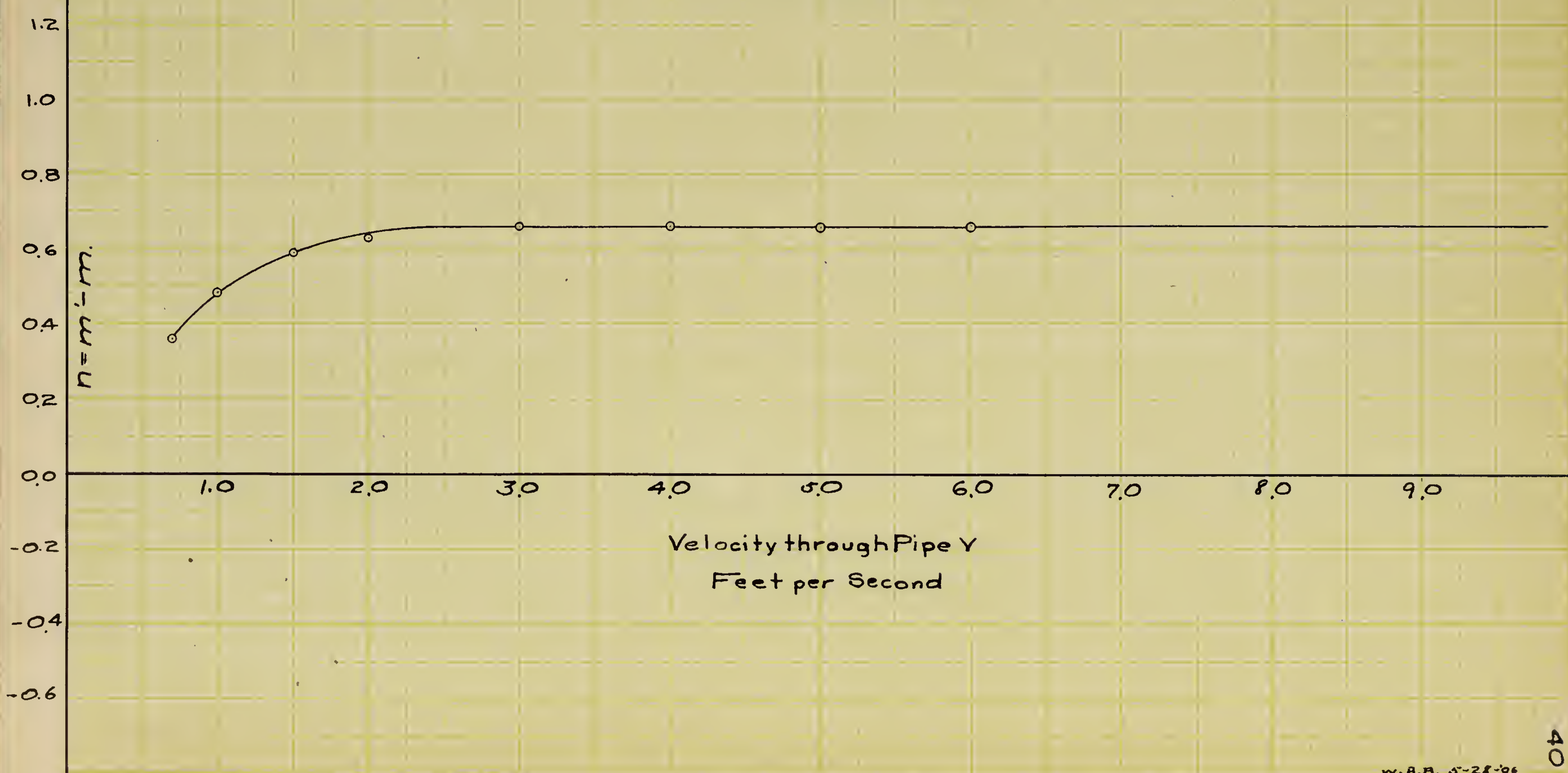


PLATE 25.

Curve Showing Relation
Between V and n
for
6-in. Pipe with 5°(1-2) Mouthpiece
on Discharge End.

PLATE 26.

Curve Showing Relation
Between V and n
for
6-in. Pipe with 10°(1-3) Mouthpiece
on Discharge End.



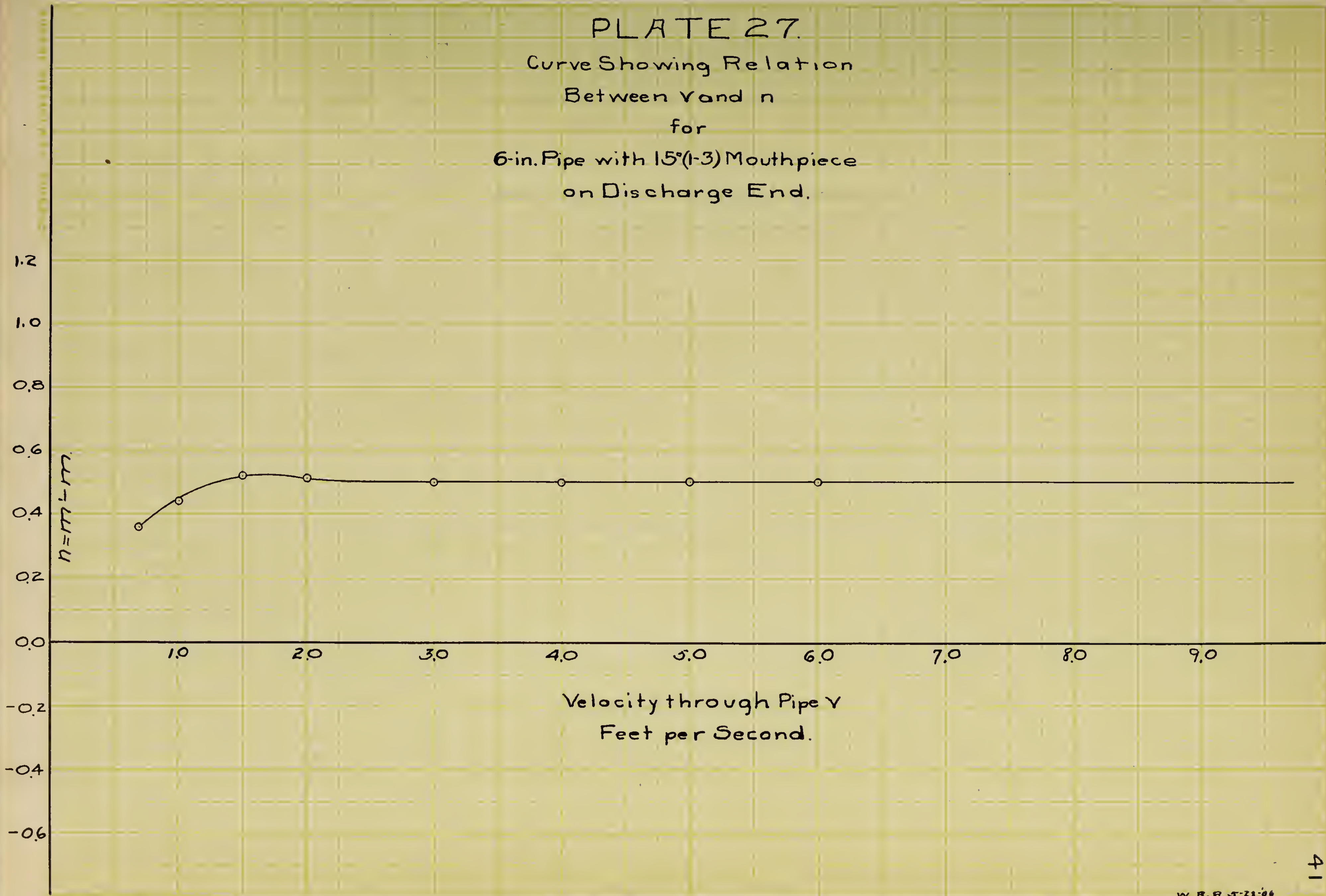
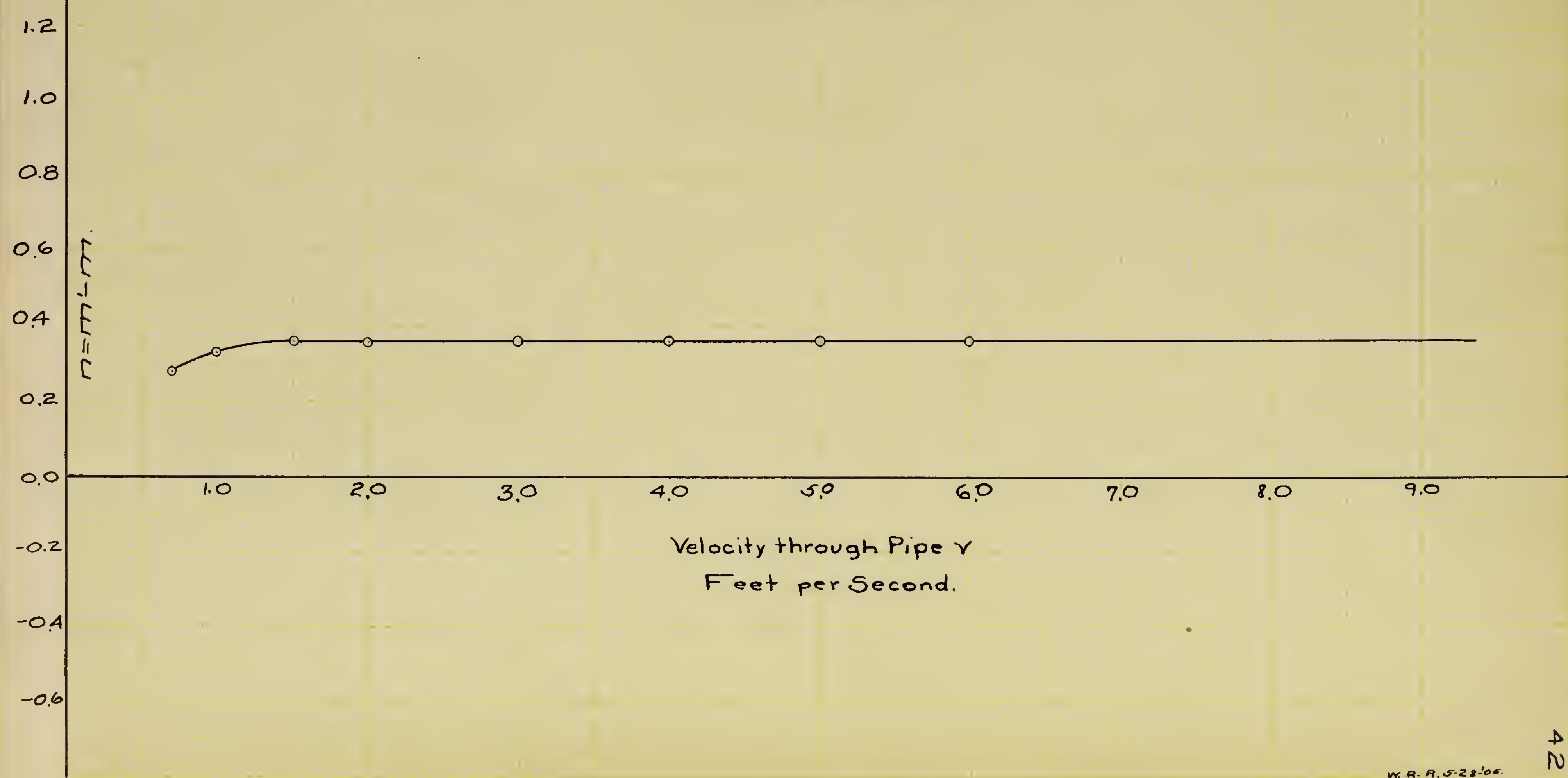


PLATE 27.
Curve Showing Relation
Between V and n
for
6-in. Pipe with 15°(1-3) Mouthpiece
on Discharge End.
n=m-m
1.2
1.0
0.8
0.6
0.4
0.2
0.0
-0.2
-0.4
-0.6
1.0
2.0
3.0
4.0
5.0
6.0
7.0
8.0
9.0
Velocity through Pipe V
Feet per Second.
W. R. R. 5-23-06

PLATE 28.

Curve Showing Relation
Between v and n
for
6-in. Pipe with 20°(1-3) Mouth piece
on Discharge End.



W. R. R. 5-28-'06.

PLATE 29.
Curve Showing Relation
Between V and n
for
6-in. Pipe with 30° (1-3) Mouthpiece
on Discharge End.

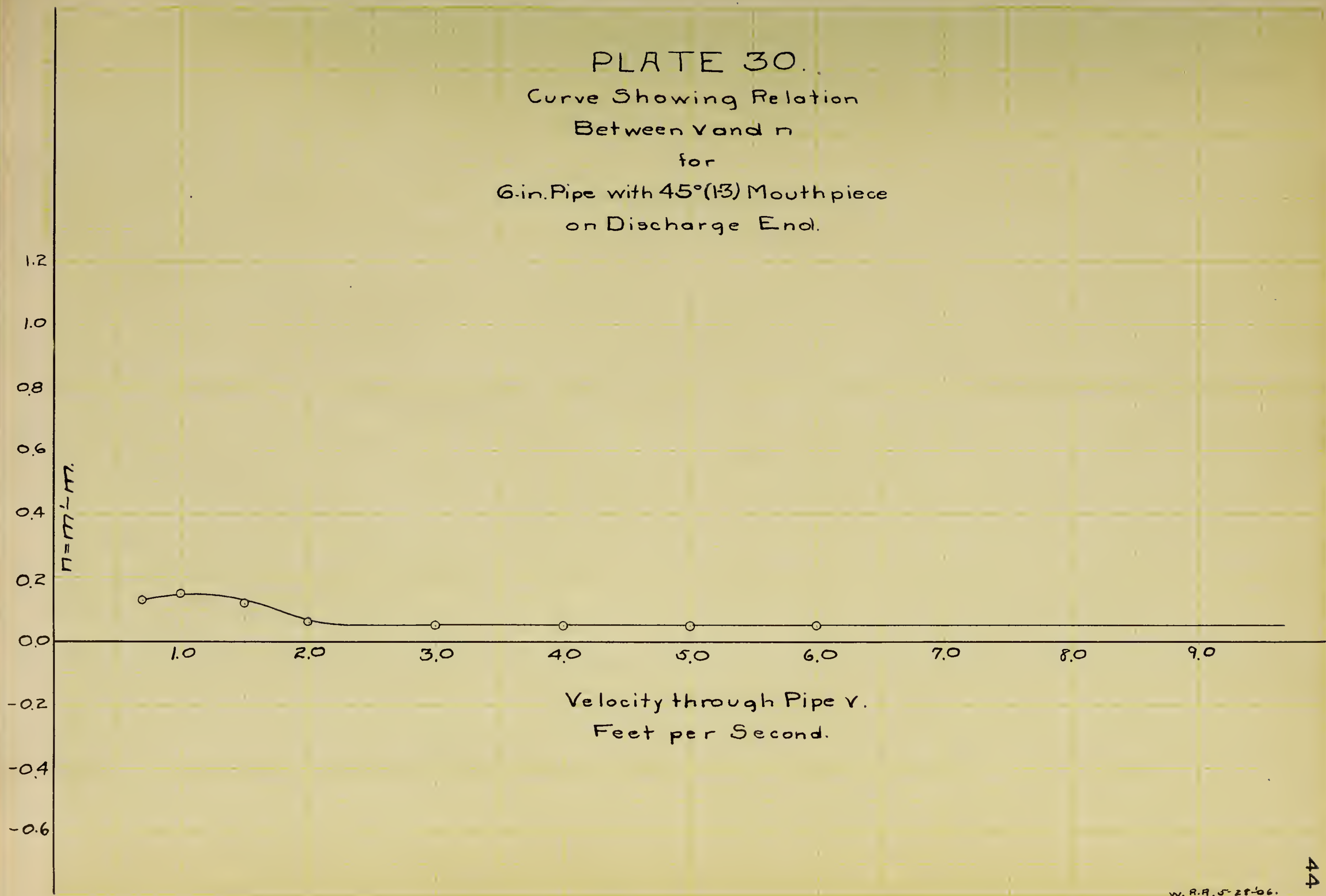
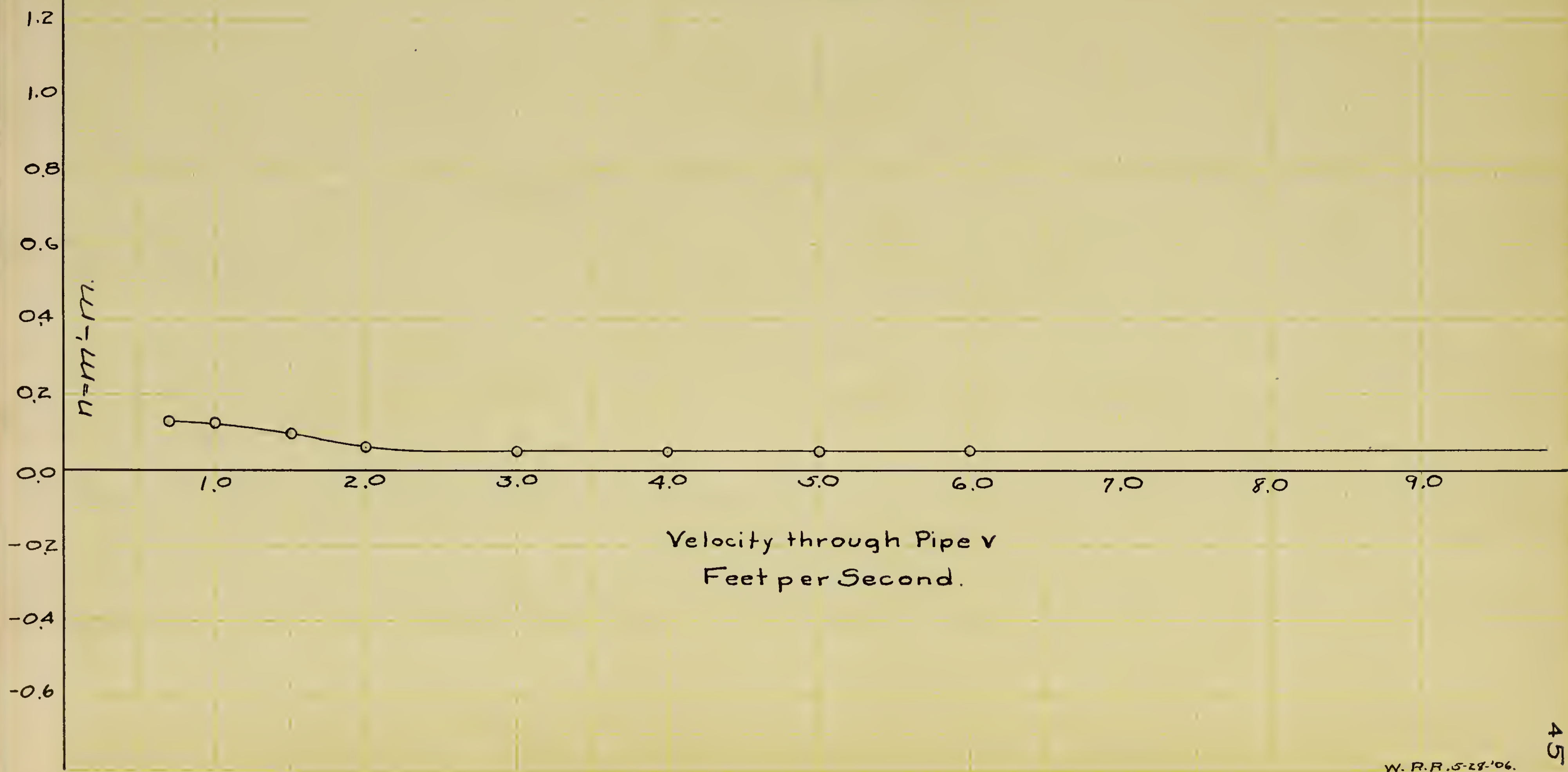


PLATE 30.
Curve Showing Relation
Between V and n
for
6-in. Pipe with 45° (13) Mouthpiece
on Discharge End.
1.2
1.0
0.8
0.6
0.4
0.2
0.0
-0.2
-0.4
-0.6
n = m' - m.
1.0
2.0
3.0
4.0
5.0
6.0
7.0
8.0
9.0
Velocity through Pipe V.
Feet per Second.
W. R. A. 5-28-06.

PLATE 31.

Curve Showing Relation
Between v and n
for
6-in. Pipe with Ring (1-3) Mouthpiece
on Discharge End.



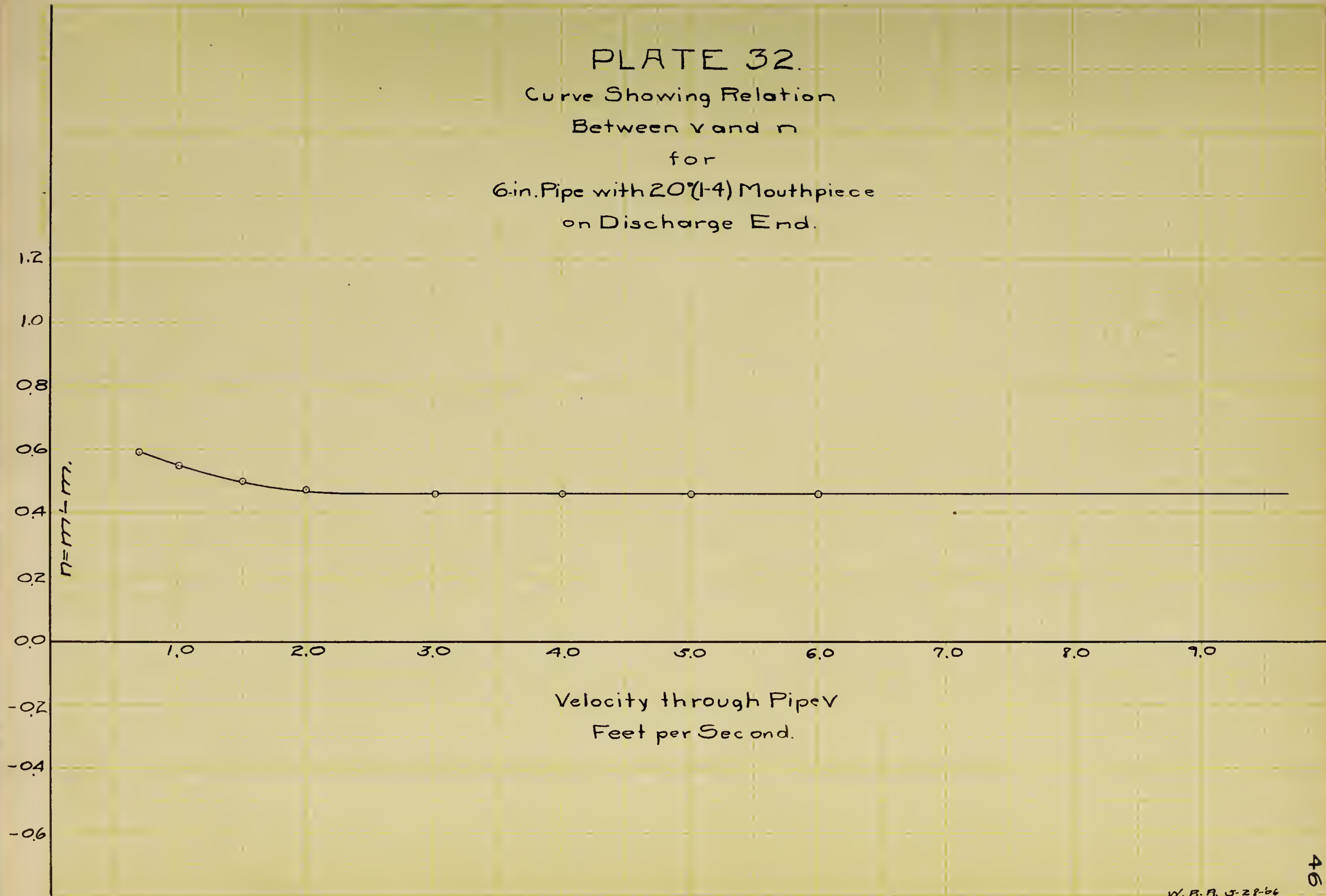
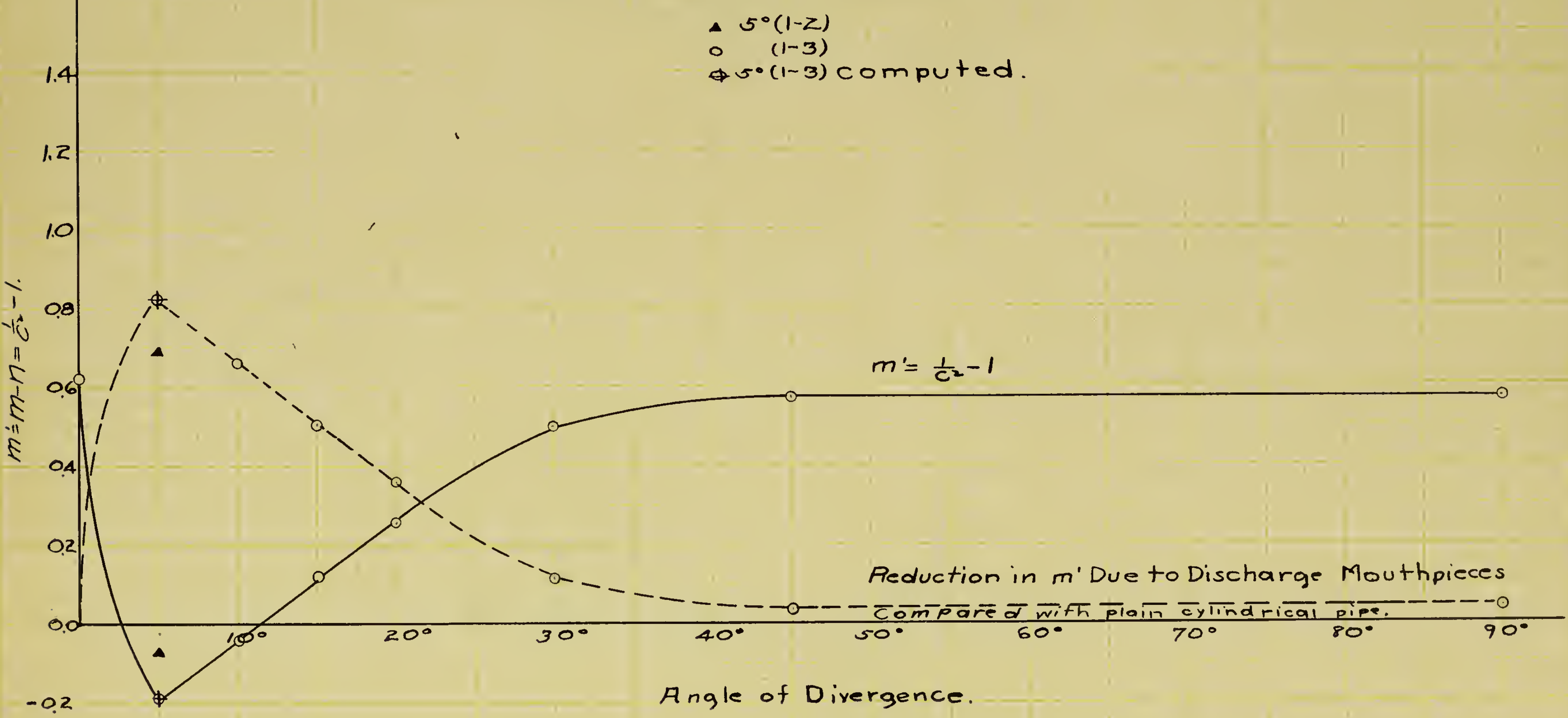


PLATE 32.
Curve Showing Relation
Between v and n
for
6-in. Pipe with 20°(1-4) Mouthpiece
on Discharge End.

PLATE 33.

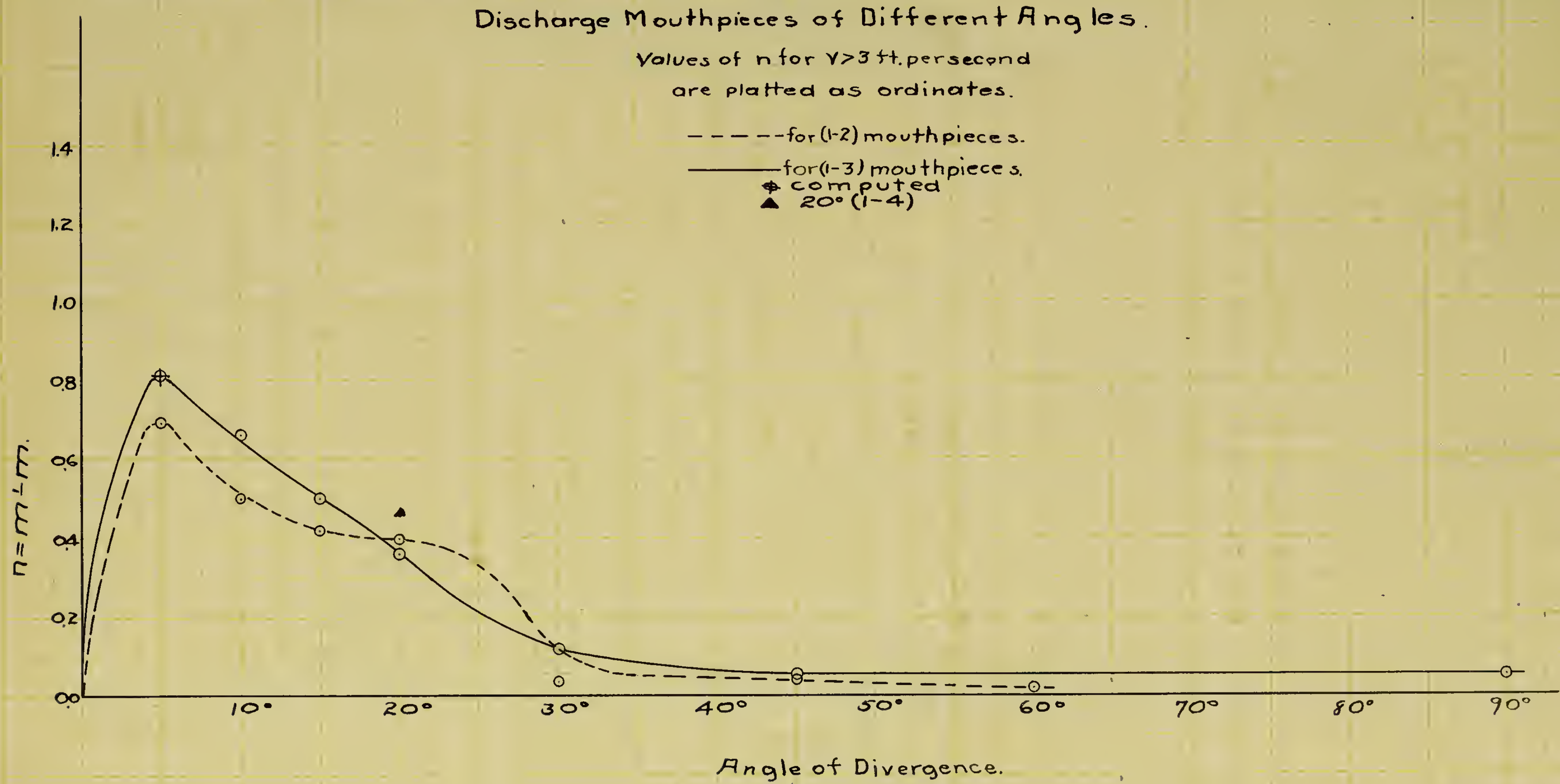
Curve Showing Variation
in m' for v >3 ft. per sec.
for
Mouthpieces of Different Angles.



W. R. R. 5-29-'06

PLATE 34.

Curve Showing Amount of Velocity Head Utilized by Discharge Mouthpieces of Different Angles.



W.A.R. 5-29-06.

TABLE 1.

1	2	3	4	5	6	7	8	9	10	11
Ref. No.	Mouthpiece Inlet End	Mouthpiece Discharge End.	Head on Pipe. Feet.	Time in Seconds	Rise in Pit. Feet.	Actual Discharge q Cu. Ft. per Sec.	Theo. Dischge Q Cu. Ft. per Sec.	Average Actual Velocity V Feet per Sec.	Coefficient of Dischge C	Coefficient of Loss (m-n)
1	0°	0°	0.016	165	0.49	0.149	0.198	0.76	0.75	0.78
2		✓	0.022	210	0.71	0.171	0.236	0.87	0.72	0.93
3			0.033	140	0.61	0.219	0.283	1.12	0.77	0.69
4			0.033	96	0.44	0.230	0.286	1.17	0.80	0.57
5			0.036	180	0.815	0.227	0.298	1.16	0.76	0.73
6			0.154	155	1.51	0.489	0.619	2.49	0.79	0.61
7			0.177	120	1.22	0.509	0.656	2.60	0.78	0.64
8			0.246	120	1.49	0.624	0.780	3.18	0.80	0.57
9			0.300	180	2.42	0.675	0.865	3.44	0.78	0.64
10			0.341	75	1.05	0.704	0.920	3.60	0.76	0.73
11			0.408	120	1.92	0.803	1.005	4.09	0.799	0.57
12			0.412	150	2.36	0.789	1.006	4.02	0.785	0.625
13			0.451	110	1.84	0.840	1.065	4.28	0.78	0.64
14			0.477	99	1.71	0.868	1.085	4.42	0.799	0.57
15	0°	5° (1-2)	0.011	180	0.595	0.166	0.168	0.85	0.99	0.02
16			0.013	180	0.590	0.165	0.179	0.84	0.92	0.18
17			0.030	160	0.89	0.279	0.273	1.42	1.02	-0.04
18			0.031	135	0.745	0.276	0.277	1.41	1.00	0.00
19			0.091	120	1.15	0.481	0.475	2.46	1.01	-0.02
20			0.092	130	1.26	0.486	0.476	2.48	1.02	-0.04
21			0.116	120	1.325	0.554	0.536	2.82	1.03	-0.06
22			0.117	115	1.285	0.561	0.538	2.86	1.04	-0.08
23			0.147	115	1.45	0.633	0.603	3.24	1.05	-0.09
24			0.148	65	0.83	0.641	0.605	3.27	1.06	-0.105
25			0.248	70	1.145	0.821	0.784	4.18	1.05	-0.09
26			0.252	85	1.40	0.829	0.790	4.22	1.05	-0.09
27			0.315	85	1.54	0.911	0.882	4.65	1.03	-0.06

1	2	3	4	5	6	7	8	9	10	11
28	0°	5° (1-2)	0.338	85	1.58	0.935	0.915	4.77	1.02	-0.04
29			0.342	85	1.61	0.952	0.920	4.85	1.03	-0.06
30			0.347	90	1.745	0.974	0.927	4.96	1.05	-0.09
31	0°	10° (1-3)	0.012	200	0.535	0.134	0.172	0.68	0.78	0.64
32			0.024	160	0.735	0.230	0.244	1.17	0.94	0.12
33			0.027	150	0.685	0.229	0.258	1.17	0.89	0.26
34			0.053	110	0.745	0.340	0.362	1.74	0.94	0.12
35			0.082	120	1.105	0.463	0.449	2.36	1.03	-0.06
36			0.089	120	1.16	0.485	0.469	2.48	1.03	-0.06
37			0.107	90	0.95	0.530	0.515	2.70	1.03	-0.06
38			0.188	120	1.64	0.686	0.681	3.50	1.01	-0.02
39			0.196	110	1.54	0.704	0.695	3.60	1.01	-0.02
40			0.331	100	1.84	0.922	0.905	4.70	1.02	-0.04
41			0.333	80	1.47	0.924	0.905	4.71	1.02	-0.04
42			0.334	105	1.93	0.923	0.910	4.70	1.01	-0.02
43	0°	15° (1-3)	0.010	220	0.69	0.157	0.192	0.80	0.82	0.49
44			0.056	120	0.85	0.356	0.371	1.81	0.96	0.09
45			0.056	120	0.835	0.350	0.371	1.79	0.945	0.12
46			0.113	120	1.19	0.497	0.528	2.53	0.94	0.12
47			0.115	140	1.41	0.506	0.534	2.58	0.95	0.11
48			0.219	145	1.95	0.675	0.735	3.44	0.92	0.18
49			0.230	135	1.92	0.714	0.754	3.64	0.95	0.11
50			0.262	125	1.895	0.761	0.805	3.88	0.945	0.12
51			0.264	120	1.76	0.736	0.806	3.76	0.915	0.20
52			0.278	115	1.79	0.781	0.829	3.98	0.945	0.12
53			0.283	140	2.22	0.798	0.836	4.06	0.955	0.10
54			0.287	135	2.14	0.795	0.841	4.05	0.945	0.12
55			0.320	105	1.745	0.835	0.890	4.26	0.94	0.12
56			0.331	95	1.66	0.878	0.905	4.48	0.97	0.06
57			0.351	110	1.925	0.878	0.933	4.48	0.94	0.12

1	2	3	4	5	6	7	8	9	10	11	
58	0°	20° (1-3)	0.008	150	0.300	0.100	0.141	0.51	0.71	0.98	omit
59			0.008	135	0.285	0.100	0.141	0.51	0.71	0.98	
60			0.011	240	0.670	0.140	0.165	0.71	0.85	0.39	omit
61			0.010	240	0.675	0.140	0.157	0.71	0.89	0.26	
62			0.028	180	0.815	0.228	0.263	1.16	0.87	0.32	
63			0.029	130	0.60	0.232	0.268	1.18	0.87	0.32	
64			0.048	110	0.655	0.299	0.344	1.32	0.87	0.32	
65			0.049	110	0.67	0.306	0.347	1.56	0.88	0.29	
66			0.138	90	0.90	0.502	0.584	2.56	0.86	0.35	
67			0.141	130	1.35	0.521	0.591	2.66	0.88	0.29	
68			0.196	75	0.93	0.623	0.696	3.18	0.895	0.25	
69			0.196	70	0.86	0.617	0.696	3.14	0.89	0.26	
70			0.268	100	1.465	0.736	0.814	3.76	0.905	0.23	
71			0.270	110	1.58	0.722	0.817	3.68	0.885	0.28	
72			0.338	85	1.420	0.839	0.914	4.27	0.92	0.18	
73			0.347	95	1.625	0.861	0.925	4.38	0.93	0.16	
74	0°	30° (1-3)	0.013	200	0.525	0.131	0.179	0.67	0.73	0.89	omit
75			0.026	130	0.525	0.203	0.256	1.03	0.79	0.61	
76			0.026	185	0.760	0.206	0.256	1.05	0.805	0.55	
77			0.066	145	0.965	0.334	0.404	1.70	0.83	0.45	
78			0.067	120	0.785	0.328	0.409	1.67	0.805	0.55	
79			0.141	117	1.135	0.487	0.590	2.49	0.83	0.45	
80			0.144	120	1.16	0.484	0.597	2.47	0.81	0.52	
81			0.167	95	0.97	0.513	0.642	2.62	0.80	0.57	
82			0.168	105	1.085	0.519	0.644	2.65	0.81	0.52	
83			0.238	100	1.24	0.622	0.768	3.17	0.81	0.52	
84			0.246	100	1.255	0.630	0.780	3.22	0.81	0.52	
85			0.385	85	1.34	0.792	0.963	4.04	0.825	0.47	
86			0.511	120	2.19	0.916	1.125	4.67	0.81	0.52	
87			0.528	105	1.96	0.937	1.14	4.78	0.82	0.49	

1	2	3	4	5	6	7	8	9	10	11
88	0°	45° (1–3)	0.011	225	0.53	0.118	0.164	0.60	0.72	0.93
89			0.029	205	0.90	0.220	0.268	1.12	0.82	0.49
90			0.031	185	0.91	0.222	0.277	1.14	0.805	0.55
91			0.073	165	1.15	0.350	0.425	1.78	0.82	0.49
92			0.074	190	1.31	0.346	0.428	1.76	0.81	0.52
93			0.129	120	1.09	0.456	0.565	2.32	0.805	0.55
94			0.132	155	1.42	0.460	0.571	2.35	0.805	0.55
95			0.175	120	1.245	0.520	0.658	2.66	0.795	0.59
96			0.178	120	1.275	0.533	0.663	2.72	0.805	0.55
97			0.203	90	1.015	0.566	0.708	2.89	0.80	0.57
98			0.208	85	0.98	0.579	0.716	2.95	0.81	0.52
99			0.278	80	1.055	0.663	0.830	3.38	0.80	0.57
100			0.286	90	1.20	0.670	0.841	3.42	0.795	0.59
101			0.348	90	1.32	0.736	0.926	3.76	0.795	0.59
102			0.351	90	1.32	0.737	0.930	3.76	0.79	0.61
103			0.450	80	1.31	0.823	1.05	4.20	0.785	0.62
104			0.455	115	1.94	0.847	1.06	4.32	0.80	0.57
105			0.507	80	1.44	0.905	1.12	4.62	0.805	0.55
106			0.507	90	1.59	0.887	1.12	4.53	0.79	0.61
107	0°	Ring (1-3)	0.008	220	0.455	0.104	0.140	0.54	0.74	0.82
108			0.009	165	0.345	0.105	0.149	0.54	0.73	0.89
109			0.022	180	0.67	0.187	0.234	0.95	0.80	0.57
110			0.055	140	0.815	0.292	0.368	1.49	0.795	0.59
111			0.057	140	0.815	0.292	0.375	1.49	0.78	0.64
112			0.137	120	1.13	0.472	0.582	2.40	0.81	0.52
113			0.210	85	0.985	0.582	0.721	2.96	0.805	0.54
114			0.211	75	0.855	0.573	0.722	2.92	0.795	0.59
115			0.220	140	1.645	0.591	0.738	3.01	0.80	0.57
116			0.272	80	1.04	0.652	0.820	3.32	0.795	0.59
117			0.320	78	1.10	0.708	0.889	3.61	0.795	0.59

omit

1	2	3	4	5	6	7	8	9	10	11
118	0°	Ring (1-3)	0.352	65	0.965	0.745	0.934	3.79	0.80	0.57
119			0.361	85	1.285	0.759	0.945	3.88	0.805	0.54
120			0.468	80	1.375	0.864	1.074	4.40	0.80	0.57
121			0.484	80	1.40	0.880	1.09	4.49	0.805	0.54
122	0°	20° (1-4)	0.024	170	0.75	0.221	0.244	1.13	0.905	0.23
123			0.025	170	0.77	0.227	0.249	1.16	0.91	0.21
124			0.054	110	0.72	0.328	0.367	1.67	0.895	0.25
125			0.055	105	0.69	0.330	0.368	1.68	0.90	0.24
126			0.101	105	0.95	0.454	0.501	2.31	0.905	0.23
127			0.101	105	0.96	0.459	0.501	2.34	0.92	0.18
128			0.132	110	1.15	0.525	0.571	2.68	0.92	0.18
129			0.133	95	0.99	0.524	0.574	2.67	0.915	0.20
130			0.210	85	1.15	0.679	0.720	3.46	0.94	0.12
131			0.257	80	1.19	0.746	0.796	3.81	0.94	0.12
132			0.260	90	1.34	0.747	0.803	3.81	0.93	0.16
133			0.354	80	1.39	0.874	0.935	4.45	0.935	0.14
134			0.464	80	1.58	0.991	1.071	5.06	0.925	0.17
135			0.467	72	1.46	1.019	1.072	5.20	0.95	0.11
136	20° (1-3)	0°	0.018	210	0.80	0.191	0.211	0.98	0.905	0.225
137			0.043	150	0.895	0.299	0.325	1.53	0.92	0.18
138			0.044	135	0.80	0.298	0.328	1.52	0.91	0.21
139			0.080	150	1.225	0.410	0.446	2.09	0.92	0.18
140			0.098	125	1.14	0.458	0.493	2.34	0.93	0.16
141			0.098	145	1.32	0.457	0.493	2.33	0.93	0.16
142			0.135	110	1.16	0.529	0.578	2.70	0.915	0.195
143			0.139	100	1.09	0.549	0.586	2.80	0.94	0.12
144			0.177	100	1.235	0.620	0.660	3.16	0.94	0.12
145			0.178	100	1.24	0.623	0.664	3.18	0.94	0.12
146			0.225	96	1.335	0.700	0.746	3.57	0.94	0.12
147			0.230	100	1.410	0.709	0.753	3.61	0.94	0.12

1	2	3	4	5	6	7	8	9	10	11
148	20° (1-3)	0°	0.259	90	1.31	0.731	0.800	3.72	0.915	0.195
149			0.357	74	1.29	0.875	0.940	4.45	0.93	0.16
150			0.358	95	1.67	0.883	0.940	4.50	0.94	0.12
151	20° (1-3)	5° (1-2)	0.011	180	0.775	0.216	0.165	1.10	1.31	-0.415
152			0.012	150	0.635	0.212	0.172	1.108	1.24	-0.35
153			0.027	165	1.05	0.319	0.258	1.63	1.24	-0.35
154			0.027	120	0.78	0.326	0.258	1.66	1.26	-0.375
155			0.040	100	0.87	0.436	0.314	2.22	1.39	-0.485
156			0.042	140	1.17	0.419	0.322	2.14	1.30	-0.41
157			0.058	95	0.96	0.506	0.379	2.58	1.34	-0.44
158			0.061	100	1.05	0.526	0.387	2.69	1.36	-0.46
159			0.091	90	1.15	0.641	0.473	3.27	1.36	-0.46
160			0.092	95	1.22	0.645	0.478	3.29	1.35	-0.45
161			0.131	85	1.31	0.775	0.569	3.95	1.36	-0.46
162			0.132	95	1.48	0.784	0.574	4.00	1.37	-0.465
163			0.159	85	1.47	0.868	0.627	4.41	1.38	-0.475
164			0.164	65	1.13	0.874	0.638	4.45	1.37	-0.465
165			0.183	77	1.44	0.940	0.673	4.80	1.39	-0.485
166			0.191	80	1.55	0.974	0.686	4.96	1.42	-0.50

TABLE 2
Values of m-n, m, and n.

Mouthpiece.		Y = 0.7			Y = 1.0			V = 1.5			V = 2.0			V = 3.0			V = 4.0			V = 5.0			Y = 6.0		
Inlet.	Disch'ge	m-n	m	n	m-n	m	n	m-n	m	n	m-n	m	n	m-n	m	n	m-n	m	n	m-n	m	n	m-n	m	n
0°	0°	0.94	0.94	0.0	0.81	0.81	0.0	0.69	0.69	0.0	0.63	0.63	0.0	0.62	0.62	0.0	0.62	0.62	0.0	0.62	0.62	0.0	0.62	0.62	0.0
0°	5° (1-2)	0.26	0.94	0.68	0.19	0.81	0.62	-0.02	0.69	0.71	-0.06	0.63	0.69	-0.07	0.62	0.69	-0.07	0.62	0.69	-0.07	0.62	0.69	-0.07	0.62	0.69
0°	10° (1-3)	0.58	0.94	0.36	0.33	0.81	0.48	0.10	0.69	0.59	0.0	0.63	0.63	-0.04	0.62	0.66	-0.04	0.62	0.66	-0.04	0.62	0.66	-0.04	0.62	0.66
0°	15° (1-3)	0.58	0.94	0.36	0.37	0.81	0.44	0.17	0.69	0.52	0.12	0.63	0.51	0.12	0.62	0.50	0.12	0.62	0.50	0.12	0.62	0.50	0.12	0.62	0.50
0°	20° (1-3)	0.66	0.94	0.28	0.48	0.81	0.33	0.33	0.69	0.36	0.27	0.63	0.36	0.26	0.62	0.36	0.26	0.62	0.36	0.26	0.62	0.36	0.26	0.62	0.36
0°	30° (1-3)	0.86	0.94	0.08	0.67	0.81	0.14	0.54	0.69	0.15	0.50	0.63	0.13	0.50	0.62	0.12	0.50	0.62	0.12	0.50	0.62	0.12	0.50	0.62	0.12
0°	45° (1-3)	0.81	0.94	0.13	0.66	0.81	0.15	0.57	0.69	0.12	0.57	0.63	0.06	0.57	0.62	0.05	0.57	0.62	0.05	0.57	0.62	0.05	0.57	0.62	0.05
0°	Ring (1-3)	0.81	0.94	0.13	0.69	0.81	0.12	0.59	0.69	0.10	0.57	0.63	0.06	0.57	0.62	0.05	0.57	0.62	0.05	0.57	0.62	0.05	0.57	0.62	0.05
20° (1-3)	0°	0.29	0.29	0.0	0.23	0.23	0.0	0.17	0.17	0.0	0.15	0.15	0.0	0.14	0.14	0.0	0.14	0.14	0.0	0.14	0.14	0.0	0.14	0.14	0.0
20° (1-3)	5° (1-2)	-0.17	0.29	0.46	-0.32	0.23	0.55	-0.41	0.17	0.58	-0.45	0.15	0.60	-0.47	0.14	0.61	-0.47	0.14	0.61	-0.47	0.14	0.61	-0.47	0.14	0.61
0°	20° (1-4)	0.35	0.94	0.59	0.26	0.81	0.55	0.19	0.69	0.50	0.16	0.63	0.47	0.16	0.62	0.46	0.16	0.62	0.46	0.16	0.62	0.46	0.16	0.62	0.46

W. R. R. 5-29-'06

TABLE 3

Mean values of m-n.

Mouthpiece.		Coefficient of loss m-n	
Inlet End	Discharge End	$r = 0.7$	$r > 3.0$
0°	0°	0.94	0.62
0°	5° (1-2)	0.26	-0.07
0°	10° (1-3)	0.58	-0.04
0°	15° (1-3)	0.58	0.12
0°	20° (1-3)	0.66	0.26
0°	30° (1-3)	0.86	0.50
0°	45° (1-3)	0.81	0.57
0°	Ring (1-3)	0.81	0.57
20° (1-3)	0°	0.29	0.14
20° (1-3)	5° (1-2)	-0.17	-0.47
0°	20° (1-4)	0.35	0.16

W. R. R. 5-29-'06

TABLE 4.

Reduction in m′ by using mouthpieces
Compared with a plain cylindrical pipe.

Mouthpiece		Reduction in m′.							
Inlet End	Dis. End.	v=0.7	v=1.0	v=1.5	v=2.0	v=3.0	v=4.0	v=5.0	v=6.0
0°	5° (1-2)	0.68	0.62	0.71	0.69	0.69	0.69	0.69	0.69
0°	10° (1-3)	0.36	0.48	0.59	0.63	0.66	0.66	0.66	0.66
0°	15° (1-3)	0.36	0.44	0.52	0.51	0.50	0.50	0.50	0.50
0°	20° (1-3)	0.28	0.33	0.36	0.36	0.36	0.36	0.36	0.36
0°	30° (1-3)	0.08	0.14	0.15	0.13	0.12	0.12	0.12	0.12
0°	45° (1-3)	0.13	0.15	0.12	0.06	0.05	0.05	0.05	0.05
0°	Ring (1-3)	0.13	0.12	0.10	0.06	0.05	0.05	0.05	0.05
20° (1-3)	0°	0.65	0.58	0.52	0.48	0.48	0.48	0.48	0.48
20° (1-3)	5° (1-2)	1.11	1.13	1.10	1.08	1.09	1.09	1.09	1.09
0°	20° (1-4)	0.59	0.55	0.50	0.47	0.46	0.46	0.46	0.46

W. R. R. 5-29-06.

TABLE 5.

Values of m for Inlet Mouthpieces.

	Mouthpiece	Coefficient of Entrance Head, m.					
		v = 0.7	v = 1.0	v = 1.5	v = 2.0	v = 3.0	v = 6.0
†	Cylindrical	1.06	0.82	0.68	0.64	0.63	0.62
†	10° (1-2)	0.56	0.36	0.22	0.20	0.18	0.18
†	15° (1-2)	0.54	0.36	0.22	0.19	0.18	0.17
†	20° (1-2)	0.40	0.26	0.20	0.20	0.20	0.20
	20° (1-3)	0.29	0.23	0.17	0.15	0.14	0.14
†	30° (1-2)	0.50	0.34	0.24	0.20	0.18	0.18
†	45° (1-2)	0.66	0.50	0.34	0.28	0.24	0.24
★	60° (1-2)	——	——	——	——	——	0.28

† Wiley. ★ Ireland.

TABLE 6.

Values of n for Discharge Mouthpieces.

	Mouthpiece	Coefficient of Discharge Head, n.					
		v = 0.7	v = 1.0	v = 1.5	v = 2.0	v = 3.0	v = 6.0
⊙	Cylindrical	0.0	0.0	0.0	0.0	0.0	0.0
	5° (1-2)	0.68	0.62	0.71	0.69	0.69	0.69
⊙	10° (1-2)	0.38	0.46	0.50	0.51	0.51	0.50
	10° (1-3)	0.36	0.48	0.59	0.63	0.66	0.66
⊙	15° (1-2)	0.50	0.44	0.44	0.44	0.43	0.42
	15° (1-3)	0.36	0.44	0.52	0.51	0.50	0.50
⊙	20° (1-2)	0.60	0.50	0.44	0.42	0.41	0.40
	20° (1-3)	0.28	0.33	0.36	0.36	0.36	0.36
	20° (1-4)	0.59	0.55	0.50	0.47	0.46	0.46
⊕	30° (1-2)	-0.04	-0.01	0.02	0.03	0.04	0.04
	30° (1-3)	0.08	0.14	0.15	0.13	0.12	0.12
⊙	45° (1-2)	0.14	0.08	0.04	0.03	0.04	0.04
	45° (1-3)	0.13	0.15	0.12	0.06	0.05	0.05
⊙	60° (1-2)	0.00	-0.06	-0.04	-0.03	0.01	0.02
	Ring (1-3)	0.13	0.12	0.10	0.06	0.05	0.05

⊙ Wiley's results.
⊕ Computed by Wiley.

W. R. R. 5-29-06.